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ECONOMIC IMPACT OF ACID RAIN

HEARING

BEFORE THE

SELECT COMMITTEE ON SMALL BUSINESS

AND THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

UNITED STATES SENATE

NINETY-SIXTH CONGRESS

SECOND SESSION

ON

ECONOMIC IMPACT OF ACID RAIN

SEPTEMBER 23, 1980

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ECONOMIC IMPACT OF ACID RAIN

TUESDAY, SEPTEMBER 23, 1980

U.S. SENATE,
SELECT COMMITTEE ON SMALL BUSINESS AND THE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS,
Washington, D.C.

The committees met, pursuant to notice, at 9:15 a.m., in room 424, Russell Senate Office Building, Senator Gaylord Nelson (chairman of the Select Committee on Small Business) and Senator George J. Mitchell, presiding.

Present: Senators Nelson, Mitchell, Stafford, and Boschwitz.

Also present: G. Thomas Cator, staff economist; Rebecca Wodder, office of Senator Nelson; Kathleen Morgan, staff assistant; and Dorothy C. Olson, staff assistant.

STATEMENT OF HON. GAYLORD NELSON, A U.S. SENATOR FROM THE STATE OF WISCONSIN, AND CHAIRMAN, SENATE SMALL BUSINESS COMMITTEE

Senator NELSON. This hearing today is a joint hearing of the Select Committee on Small Business and the Environment and Public Works Committee on the issue of acid rain. Senator Mitchell is conducting the hearing on behalf of the Environment and Public Works Committee. I will be opening the hearing on behalf of the Select Committee on Small Business.

I have an opening statement which I will make at this time. Then Senator Mitchell has an opening statement. I ask that a statement by Senator Weicker as well as a statement by Senator Levin be placed in the record following Senator Mitchell's statement.

Today's hearing concerns one of the new breed of environmental problems which we must solve in the next decade—one which has become popularly known as acid rain. Unlike the pollutants of the seventies which could be seen or smelled in and around any urban area, the pollutants of the eighties are not restricted to urban settings and go largely undetected until it is too late.

Acid rain poses a threat of monumental dimensions. Unless we begin immediately to bring this problem under control, we will see irreparable damage to our fresh water lakes, major injury to the tourist industry, and serious damage to our forests and agriculture. The economic and environmental costs will be immeasurable.

Acid rain is produced primarily by the combustion of fossil fuels, such as coal, oil, and gas, in powerplants and automobiles and in smelting processes. The phenomena will increase with greater coal use unless we set strict emission standards.

Acid rain is particularly disturbing because it does much of its damage not in the urban areas where it is generated, but in vulnerable, pristine remote areas where there is neither a smokestack nor a superhighway.

The north woods in my own State of Wisconsin fit that last description: Thousands of lakes on poorly buffered, thin soils which are being acidified by pollution which has traveled hundreds of miles. EPA scientists have told me that more than three-quarters of the 10,000 lakes in the northern half of Wisconsin are being affected by acid rain right now, and many could be sterile and devoid of fish within 10 years. If this happens, Wisconsin's $5 billion per year tourist industry could be severely impacted.

For the most part, acid rain is a slow poison without dramatic and attention-getting events such as massive fish kills. Instead, it affects sensitive fish, including salmon, trout, and walleye, by reducing the reproduction rate and killing very young fish. While the larger fish may be able to tolerate the increased acidity, there is evidence that acidification accelerates the release of mercury and other heavy metals from the lake sediments whereupon these toxic substances concentrate in fish.

I will ask that the balance of my statement be printed in full in the record in order to economize on time.

[The information referred to follows:]

The Boundary Waters Canoe Area Wilderness and Voyageurs National Park in Minnesota are similarly threatened. A new EPA study shows that many of these lakes have reached a critical level of acidity, and any more acid may tip the balance.

Acidification of lakes is also underway in the Great Smoky Mountains of North Carolina and Tennessee, Shenandoah National Park in Virginia, the Pine Barrens of New Jersey, and the trout streams of West Virgina. Acid rain is falling on susceptible areas from Acadia National Park in Maine to the Colorado Rockies.

To date, most of the attention to the problem of acid rain in the United States has been focused on the Northeast rather than the Midwest. The New York State Department of Environmental Conservation estimates that over half of the high altitude lakes in the Adirondack Mountains of New York are already "dead." The park, which is within a day's drive of 55 million people, contains much of the wilderness in the Northeastern United States. Anglers spend $16 million per year here. According to the Adirondack Park Agency, acidified lakes have already resulted in a loss of at least $1.5 million per year in sport fishing-related income.

Canadian resort owners have even more to lose. In 1975, the sport fishery of Canada's acid-susceptible region generated over $600 million for Canada's economy. The Ontario Ministry of Environment has reported that 48,000 resort lakes are threatened with irreversible damage. They estimate that within the next 20 years, 600 fishing lodges, more than 6,000 jobs, and $28 million per year in revenues from sport fishing alone could be lost.

The existing toll is highest in Scandinavia. In Sweden, 5,000 lakes are so severely acidified, they won't support fish, and another 10,000 lakes are threatened. A comprehensive study of acid rain in Norway reported that the "majority of inland waters . . . have completely lost their fish populations." Commercial salmon fishing in much of southern Norway and Sweden has been wiped out.

For the most part, acid rain is a slow poison without dramatic and attention-getting events such as massive fish kills. Instead, it affects sensitive fish, including salmon, trout, and walleye, by reducing the reproduction rate and killing very young fish. And while the larger fish may be able to tolerate the increased acidity, there is evidence that acidification accelerates the release of mercury and other heavy metals from the lake sediments whereupon these toxic substances concentrate in fish. In some resort areas, anglers are being cautioned about eating species such as walleye and northern pike, which are already showing high levels of these toxic metals.

But it is not only the lakes which are being damaged by acid rain, as today's witnesses will explain. Acid rain is taking its toll on our crops and forests, our buildings and monuments, and even on our health. As was noted at a Toronto

conference on acid rain last year, "the fish dying in acid lakes are a warning to us just as a canary dying in a coal mine warns miners."

Consider the following reports:

In southern Sweden, scientists have correlated a decrease in forest growth with acidification and are predicting a 10 to 15 percent loss by the year 2000 as nutrients are leached from the soil;

In the western Adirondacks, people are being warned to let their water run for 5 minutes in the morning to flush out water which has been sitting in the pipes all night long and which because of its increased acidity may have reacted with and dissolved some of the copper or lead from the piping;

A recent study by Brookhaven National Lab reports that acid sulfates account for 2.7 percent of all deaths in the United States, and as much as 5 to 8 percent in some areas;

Corrosive damage to construction materials, fabrics, and other surfaces is estimated to cost the United States $2 billion annually, according to a report submitted to the President's Council on Environn ental Quality.

The purpose of today's hearing is to begin to bring together the available information on these and other potential economic costs of acid rain and atmospheric deposition which result from the combustion of fossil fuels. We will be receiving testimony from economists, members of the business community, and scientists as to their best estimates on economic losses which may occur in tourism, sport and commercial fishing, agriculture and forestry, and the deterioration of buildings and works of arts, and the safety of drinking water supplies.

The hearing is being jointly held by the Committee on Environment and Public Works and the Select Committee on Small Business. I am extremely pleased to be cochairing this hearing with Senator Mitchell, who is representing the Environment and Public Works Committee.

Previous hearings held by committees of the House and Senate have addressed the causes of acid rain, the environmental effects, the adequacy of information on the phenomena, and the need for additional research. Today, we will not reexamine these questions, but rather, we will begin by saying that if the predictions on the effects and extent of acid rain turn out to be accurate, then what will be the cost to our economy? We are not attempting to assign blame for the problem, nor are we today assessing the costs of eliminating it.

Simply identifying the sectors of the economy which may suffer as a result of acid rain is a difficult task. To go further and attempt to estimate the potential economic losses and their value requires numerous assumptions, and gives us only order of magnitude values. Nonetheless, we must begin now to pull these numbers together. In the next session of Congress, the Clean Air Act will be reviewed and reauthorized. I feel very strongly that legislation to control pollutants which lead to acid rain must be included in this review. I will soon introduce a bill which would accomplish this purpose.

There are many who would argue that the jury is not in on acid rain, that we must have 10 years to study the problem before we act. While I believe that continued research is vitally necessary, we do not have the luxury of postponing any action any longer. Over 200 Adirondack lakes are already "dead." For thousands of lakes in Wisconsin, facing the same fate in the next decade, it is literally now or never.

Clearly, acid rain is an environmental threat which demands our immediate and full attention. It is a forerunner of a multitude of environmental problems which will arise out of the conflict between our desire for a high quality environment and our need for energy. Some will argue that we cannot afford the costs of clean burning of coal. The information which will be presented at today's hearing will become part of that debate.

We need our energy independence and we need a healthy environment. According to MIT Prof. Carroll L. Wilson, director of the recent MIT study titled "Coal—Bridge to the Future," "At present prices, coal is becoming the world's energy bargain par excellence, for no matter how stiff the environmental standards in effect in any country, the fuel will still remain substantially cheaper, more plentiful and more reliable than petroleum."

The full cost of satisfying our energy appetite will be paid, whether now or later. If we continue on our present path much longer, the costs will include the damages to our environment, recreation resources, forests, soil, and health. In my opinion, we will be much better able to afford the cost of preventing the damage than suffering the consequences after it occurs.

Senator NELSON. At this time I will turn the floor over to Senator Mitchell.

STATEMENT OF HON. GEORGE J. MITCHELL, A U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Thank you very much, Senator Nelson.

I am pleased to act as cochairman of this hearing this morning on the economic impact of acid rain. I appreciate your invitation and your interest in this subject, which is of particular concern to me and to the State of Maine.

It is timely that we should be discussing acid rain today. A memorandum of intent has just been signed between the United States and Canada on our mutual acid rain problem; the President has recently sent to the Congress his Federal acid rain assessment program, and the Senate approved a massive coal conversion program just this summer.

Acid rain presents a grave threat to our natural resources. Despite the fact that acid rain has only recently attracted the attention of scientists and policymakers in this country, it is already responsible for:

The loss of more than 170 lakes and ponds totaling 7,000 acres in New York State;

An eightfold increase in the acidity of Maine lakes over the past 40 years;

And a substantial decrease in forest growth in southern Sweden between 1950 and 1965.

Despite these alarming initial indications that acid rain may be a potential environmental disaster for our resources, we are nationally embarking on an energy program based in large part on the use of coal. The burning of dirty coal has been the primary source of acid rain.

So we are presented with a dual challenge: to prevent increases in existing acid rain levels and to reduce existing levels.

One of the most critical problems surrounding the discussion of acid rain is the lack of consensus as to the adverse environmental impacts of this pollution on our natural resources. But at least we have some numbers and figures to work with.

A more troublesome problem is the virtual nonexistence of data on the economic impacts of acid rain damage.

As in all environmental debates, the costs of controlling emissions of the facilities contributing to acid rain levels are readily available. But quantifying the costs of the damage is far more difficult. Commonsense tells us that if our lakes and their fishlife are dying, our forests are yielding less timber, and our buildings are crumbling, these damages represent real economic losses.

It is my hope that we will be educated by our witnesses today about the economic impact of acid rain. It is my belief that the resolution of the acid rain problem has its roots in an understanding of both the economic costs to our resources as well as the costs of control by all parties—including the Government, industry, and the public we all serve.

Thank you.

Senator NELSON. Thank you, Senator Mitchell.

Senator Boschwitz?

Senator BOSCHWITZ. I have no statement, Mr. Chairman.

[The prepared statements of Senators Weicker and Levin follow:]

STATEMENT OF SENATOR LOWELL P. WEICKER, JR.

Mr. Chairman, the problem of acid rain has become a matter of serious concern on both the national and international levels. Many scientists believe that this phenomenon is responsible for the sterilization of hundreds of lakes in both the United States and Canada. These lakes now stand devoid of fish and other forms of aquatic life, in effect an omen of what the future may hold for us if we refuse to control acid rain.

Scientists in Sweden report that they have noticed a decrease in tree growth in recent years, and they attribute this to an increase in the acidity of precipitation. Should this condition occur in the U.S., states such as New Hampshire, which depends on timber and its ancillary business for a large part of its commerce, could suffer severe economic dislocation.

Acid rain has also been blamed for crop damage, decreased soil fertility, corrosion of manmade materials and structures and visibility reduction as well as adverse affects on human health.

In the 1980's acid rain could very well become a serious public health hazard. Inhalation of acid mist may result in lung problems such as emphysema. Further research may show that exposure to acid rain could cause skin and eye irritation.

Acid rain threatens to reduce agricultural crop yields because it causes nutrients to leach from the soil. Furthermore, acid rain can also accelerate the bioaccumulation of toxic metals from the soil, to grain and to other agricultural crops, and to cattle.

Drinking water supplies are also theatened by the leaching of toxic metals either from the watershed or from pipes that corrode from contact with the acidic water.

Mr. Chairman, I am aware that there is substantial debate over the causes, affects, and solutions to the acid rain problem. In its 1979 annual report, the Council on Environmental Quality concluded that "insufficient knowledge exists about the explicit causes and the total affects of acid rain * * *" Yet, at the same time other members of the scientific community argue that studies indicate that most of the problem results from the long range transport by the prevailing winds of air pollutants from fuel burning in the highly industrialized and urbanized areas in the Midwest.

The response to the charge that the utility industry is the prime culprit in the acid rain controversy has been that there is no data base to prove it. Industry representatives argue that there has not been a correlation drawn between emissions from a powerplant's smokestack in one region causing acid precipitation in another area.

Finding a solution to the acid rain problem will not be easy until the phenomenon has been thoroughly examined. However, it presently appears that stricter and more uniform standards on emissions will be needed nationwide. These standards must apply to utilities and chemical refineries as well as to automobiles and other major pollution sources. In addition, retrofitting of powerplants with scrubbers will be essential if the pattern of increasingly acidic precipitation is to be reversed. This effort to arrest the acid precipitation problem will also generate discussion as to how the cost of this cleanup will be distributed equitably throughout society.

I look forward to reviewing the testimony of the Committee's witnesses in this regard. I will also be interested in obtaining their assessment of the cost to the economy of the damages caused by acid rain. Their recommendations as to the solution of this critical problem are eagerly awaited.

STATEMENT OF SENATOR CARL LEVIN

Thank you Mr. Chairman. The problem of acid rain is one that has only recently come to public attention. As Congress increasingly shifts American energy consumption habits toward a greater reliance on coal, we have come to realize that we have to mitigate, if not prevent the problems caused by that shift. I welcome the opportunity offered by this hearing to learn more about this problem and thank Senator Nelson for providing it.

Acid precipitation is expected to increase in the future. Already, acid rains and snows have wiped out entire fish populations of half the high-altitude lakes in New York State's Adirondack Park and significantly diminished fish populations in Wisconsin, Minnesota, Oregon and the Eastern seaboard. It is even reported that the acid rain which falls on Alaska is produced in Japan—one more Japanese import we could do without. The Taj Mahal in India is said to be crumbling from the effects of acid rain and Canada's Minister of the Environment calls acid rain his nation's "worst environmental problem."

Michigan has also been affected by acid rain, although a combination of factors have made it a bit more fortunate, for the time being, than the places I have already mentioned. The presence of heavy industry in Michigan has probably made my state a net producer of acid precipitation. Michigan's existence as both a large producer and a large consumer of acid rain has vividly revealed to me the difficulty we face in devising a rational policy to deal with this phenomenon.

It is with great curiosity and interest therefore that I await the testimony of our witnesses here this morning.

Senator NELSON. We have 12 witnesses this morning. Our first panel will consist of Mr. Bob Martini, Wisconsin Department of Natural Resources; Mr. Jay Heffern, assistant executive director, Minnesota Pollution Control Agency; Ms. Barbara Gass, Michigan Department of Natural Resources; and Dr. Stephen Norton, University of Maine.

Would the witnesses, starting at my left, please identify themselves so that the reporter will accurately attribute their comments?

Ms. GASS. My name is Barbara Gass, air quality division, Michigan Department of Natural Resources.

Mr. HEFFERN. I am Jay Heffern, assistant executive director, Minnesota Pollution Control Agency.

Mr. MARTINI. I am Bob Martini, north-central district of the Wisconsin Department of Natural Resources.

Dr. NORTON. I am Stephen Norton from the University of Maine at Orono.

Senator NELSON. Our first witness this morning will be Mr. Bob Martini, Wisconsin Department of Natural Resources.

The committees are pleased to have you here this morning, Mr. Martini.

I had the opportunity to be introduced to the problem respecting the lakes of Wisconsin by Mr. Martini this summer in some studies that are being conducted by the Department of Natural Resources and I believe by the EPA also, jointly; is that correct?

Mr. MARTINI. Yes.

Senator NELSON. Go ahead, Mr. Martini. It would be worthwhile for the record if you would recite briefly your experience in Wisconsin with this problem.

STATEMENT OF BOB MARTINI, NORTH CENTRAL DISTRICT, WISCONSIN DEPARTMENT OF NATURAL RESOURCES

Mr. MARTINI. For the past year and a half I have been directing efforts to assess the potential problems of acid deposition in Wisconsin, including the susceptibility of our resources, the condition of the precipitation that is falling in Wisconsin, and some of the political problems we are having in dealing with the problem.

A copy of the report outlining our findings is submitted for the record.

[The information referred to follows:]

CORRESPONDENCE/MEMORANDUM — STATE OF WISCONSIN

Date: June 30, 1980 File Ref: 3350

To: Anthony S. Earl - ADM/5

From: Tom Sheffy - Water Quality Evaluation Section TBS
WQ/2

Subject: Final Report From Acid Deposition Task Force

As requested in your February 14, 1980 memorandum, the Acid Deposition Task Force has completed the attached report.

As Task Force Chairman, I am forwarding the report for your approval. I call your particular attention to the summary of findings, recommendations for emission controls, research needs, and budget request.

TS:jm
Attachment
cc: J. McKenzie - WPE/2
C. Blaboun - WQ/2
F. Schraufnagel - WQ/2
Y. Kroehn - ADM/5

APPROVED:

Anthony S. Earl, Secretary — Date 7/11/80

Proposed budget requests will receive full review during the upcoming Budget process. AE

AO-76

A REVIEW OF ACID DEPOSITION IN WISCONSIN; RECOMMENDATIONS FOR STUDYING AND SOLVING THE PROBLEM

Prepared By:

Department of Natural Resources
Acid Deposition Task Force

June 1980

T.B. Sheffy, Chairman - Water Quality
R. Martini, Vice-Chairman - N.C. District
D. Knauer - Inland Lake Renewal
W. Meiser ol - Information and Education
A. Prey - orestry
W. Adamski - Air Management
W. Threinen - Fish Management
T. Wirth - Water Research
D. Theiler - Administration
W. Sprague - Environmental Impact
J. Morton - Air Management

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PREFACE

Research performed in Scandinavia, Canada and New York links acid precipitation to the disappearance of sport fish and other organisms from lakes that once supported a diversity of aquatic life. In vulnerable areas acid precipitation also threatens to impair soil fertility, forest and agricultural production and tourism if the sources of its air pollution precursors are not identified and controlled.

Northern Wisconsin possesses environmental features very similar to regions already damaged by acid precipitation. These areas are prized by residents and visitors for their scenery, fish and wildlife and varied recreational opportunities. They are commercially important for timber, tourism and some agriculture.

Preliminary research conducted on Wisconsin lakes underscores their high susceptibility to acid precipitation. In addition, rain collected and analyzed in Wisconsin in 1979 was found to be at least ten times more acid than normal--the same level recorded in New York's Adirondack Mountains where many high-altitude lakes now are devoid of fish. With an increasing reliance on coal in the United States, the acid rain problem is likely to increase in the near future. For these reasons, "Acid Rain" in Wisconsin has recently surfaced as a major public concern.

In an effort to assess the potential problem, Department of Natural Resources Secretary, Anthony Earl, created an Acid Deposition Task Force in February 1980.

The Task Force consists of a multi-disciplinary team of eleven professionals from the North Central District, various bureaus, including Water Quality, Water Resources Research, Air Management, Fish Management, Environmental Impact, Forest Management, Inland Lake Renewal, Information and Education, and Department administration.

The Task Force was given the charge of evaluating the acid deposition problem, using a multi-discipline approach to assess the potential impact on Wisconsin's resources, and to propose solutions. This report summarizes the findings of the Task Force regarding the current problem of acid deposition, and states goals, objectives, and recommendations for solving the problem.

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GLOSSARY OF TERMS

Acid bog lake - Normally a seepage lake in a region of non-calcareous soils which has undergone natural, successional changes over several centuries. All lakes are subject to this process, but it occurs very slowly, and normally results in a small, shallow, acidic lake (pH 4-6) having extremely low alkalinity and acid-tolerant biota (sphagnum-leather leaf-tamarack community; fish population often includes stunted panfish and small northern pike). These types of lakes are common in northern Wisconsin and existed long before the occurrence of acid rain. Because of their already low pH acid bog lakes are extremely susceptible to further acid loading, but in these lake types it is often difficult, if not impossible, to separate acidification due to natural processes from acidification due to the more recent phenomenon of acid rain.

Acid deposition - The total process by which acids precipitate from the atmosphere onto land surface, physical objects or water.

Acid loading - The quantification of acid deposition from all sources, both wet and dry.

Acid rain - Popularized phrase meaning any rain with a pH less than 5.6 (normal rain is pH 5.6).

Acid rain precursors - Sulfur dioxide, nitrogen oxides, and other pollutants which are the initial air pollutants transformed into sulfuric and nitric acids.

Acid shock - A sudden surge of low pH water into an aquatic system. It can occur during the spring thaw when ice and snow containing large amounts of acid deposition from the winter months melt in a short time, causing acid meltwater to gush into lakes and streams. Acid shock can kill eggs, larvae and adult fish by creating a sudden pH decrease.

Alkalinity - A measurement of dissolved carbonates in water. These dissolved carbonates ($CaCO_3$ or $MgCO_3$) act to neutralize any acids that are added to aquatic systems.

Base - Any substance having a pH greater than 7; often neutralizes acids.

Benthic - Referring to the bottom of a lake or stream.

Buffering capacity - The ability of water or soil to neutralize acids; depends on alkalinity. An alkalinity of 200 mg/l $CaCO_3$ is high and provides a lake with high buffering capacity; an alkalinity of 5 is low and provides a lake with very little buffering capacity.

Calcareous soil - Soil derived from dolomite having high concentrations of $CaCO_3$ and $MgCO_3$, which can neutralize acids.

Carbonic acid - H_2CO_3. A weak acid formed in normal unpolluted rainfall by the reaction of CO_2 and H_2O; accounts for the slightly acidic nature of rain, which has a normal pH of about 5.6.

Clean Air Act - Federal legislation as amended in 1977, which outlines a program to attain and maintain a high degree of air quality in the U.S. The U.S. Environmental Protection Agency is responsible for implementing and enforcing the provisions of the act.

Dolomite - Mineral consisting of calcium magnesium carbonate, $CaCO_3$-$MgCO_3$, (same as limestone) with a high capacity to neutralize acid precipitation.

Drainage lake - Lake with an inlet and outlet that usually provides a continuous and renewed supply of buffering agents and reduces lake flushing time.

Dry deposition - Acid deposition in solid form in the absence of rain; direct deposition of microscopic particles on land surface, water, plants, physical objects.

Granite - Hard igneous rock mainly composed of quartz. Not permeable to water; low capacity to neutralize acid precipitation due to its low $CaCO_3$ content (see Precambrian shield).

Granite bedrock - See Precambrian Shield.

Lake liming - Treating a lake with powdered lime or limestone in an attempt to neutralize acid and raise the pH.

Limestone - See dolomite.

Long-range transport - The process by which acid rain precursors are carried long distances (100-1,000 km) from their source by air currents in the atmosphere.

Microequivalents - The concentration (ppm or mg/l) of a substance divided by the equivalent weight x 1,000; if water has an alkalinity of 25 ppm $CaCO_3$, it has 500 microequivalents (25 mg/l ÷ 50 mg/ ueq x 1000) of bicarbonate (HCO_3^-) per liter; 500 microeqqivalents of HCO_3^- will neutralize 500 microequivalents of hydrogen ion (H^+) or one liter of water with a pH of about 3.3.

Mobile source - Moving source of air pollution, such as an automobile.

NADP - National Atmospheric Deposition Program, which establishes precipitation monitoring sites throughout the United States in an effort to document trends in acid deposition.

Nitric acid - HNO_3. A strong acid which can greatly reduce the pH of rain; results from the oxidation of nitrogen oxide pollutants in the atmosphere.

Normal rainfall - Rainfall with a pH of 5.6.

NSPS - New Source Performance Standards. A section of the Clean Air Act and a set of EPA regulations which call for strict emission standards for new or modified stationary sources of air pollutants.

pH - A numerical value used to describe the strength of an acid; derived from the hydrogen ion concentration of a solution. The pH scale ranges from 0 to 14 -- pH 1 is very acidic (battery acid), pH 7 is neutral, and pH 13 is very alkaline (lye).

Plume - The total downwind emissions cloud from a pollution source.

ppm - Parts per million. A ratio describing the concentration of one chemical in relation to another. Same as micrograms per gram (ug/g), milligrams per kilogram (mg/kg) or milligrams per liter (mg/l). A 30 ppm solution of $CaCO_3$ in water means 30 mg of $CaCO_3$ in one liter of water.

Precambrian Shield - An extensive layer of granite bedrock which lies very close to the earth's surface, sometimes exposed in much of northern Wisconsin, Minnesota and Upper Michigan. Granite bedrock is igneous rock with low permeability to water and little capacity to neutralize acids. Lakes located on the Precambrian Shield are softwater lakes with relativaly low pH and alkalinity, and are, therefore, very susceptible to further acid loading.

Precipitation event - A single precipitation occurrence. Several individual precipitation events may contribute to the total precipitation occurring in a week.

PSD - Prevention of Significant Deterioration. A section of the Clean Air Act and a set of EPA regulatic which outline a program to minimize the impact of air pollution in those areas where air pollution is currently not a problem, i.e., wilderness areas, national parks, etc.

Recruitment - A population dynamics term for the addition of young of the year to the adult population. Low pH interferes with fish reproduction so recruitment may be reduced; a population may progress to extinction as a result of no annual recruitment.

Residence time - The period of time an air pollutant remains suspended in the atmosphere before settling to the ground; long residence times favor more acid formation from sulfur dioxide and nitrogen oxide.

Sandstone - Sedimentary rock, composed mainly of quartz and silica. Low capacity to neutralize acid precipitation.

Scrubber - Flue gas desulfurization device which removes sulfur dioxide from flue gas before leaving the smokestack. Lime or limestone slurry is used to scavenge sulfur dioxide from flue gas.

Seepage lake - Lake with no inlet or outlet dependent on surface runoff, precipitation, and/or groundwater for recharge.

Stationary source - Fixed or "point" source of air pollutants, such as a coal-burning power plant.

Susceptibility - Vulnerability or sensitivity of a lake or stream to acidification due to acid deposition. Many lakes in northern Wisconsin have high susceptibility because of several factors such as low alkalinity and poorly buffered watersheds.

Sulfate - $SO_4^=$. An intermediate form of sulfur that develops as sulfur dioxide (SO_2) chemically converts to sulfuric acid (H_2SO_4).

Sulfuric acid - H_2SO_4. A strong acid which can greatly reduce the pH of rain; results from the oxidation of SO_2 pollutants in the atmosphere.

Tall stacks - Arbitrarily defined as smokestacks over 180 meters tall. Many stacks over 300 meters tall were recently built to reduce sulfur and nitrogen oxides at ground level near sources. By injecting oxides higher into the atmosphere, local SO_2-NO_x problems have become regional acid rain problems.

Wet deposition - Acid deposition in the form of liquid: rain, snow, mist, dew, or fog.

Wet/dry sampler - A device used to measure the total amount of acid deposition in both the liquid fraction and the dry particulate fraction.

SUMMARY OF FINDINGS

1. Wisconsin has a large data base on lake water quality dating back to 1925. This data indicates that about 40% of the lakes in the northern half of the state are susceptible to acidification.

2. Wisconsin's large data base on lake water quality is made up of several sets, representing different time periods. Each of these sets was collected for a different purpose, using different collection and chemical analysis methodology. While it is difficult to use the data for determining long-term trends concerning lake acidification, natural fluctuation in pH is the principal variable.

3. Based on 1979-80 in-state precipitation monitoring data, Wisconsin is presently receiving acid precipitation, pH approximately 4.5. Extrapolation of data from other national precipitation monitoring sites suggests that Wisconsin has received acid precipitation since about 1973.

4. The soils, bedrock, surficial geology, groundwater characteristics, and lake types of northern Wisconsin account for this area's general susceptibility to acid deposition.

5. Although laboratory experiments elsewhere have demonstrated harmful effects of simulated acid rain on agricultural crops and forest plant species, acid precipitation damage to vegetation in Wisconsin has not been documented (or studied) to date.

6. Approximately 10% of the lakes monitored in northern Wisconsin in 1979 showed pHs between 4.5 - 6.0. Most of the lakes in this category are small (less than 100 acres) infertile, seepage lakes which do not naturally support large, abundant, or diverse sport fish populations. These small lakes have a unique aesthetic value, are an integral part of the northern lakes ecosystem, and should therefore be protected from acidification. However, these lakes provide a very small percentage of the recreational fishery available in northern Wisconsin. Based on Canadian studies, a pH range of 4.5 - 6.0 in these lakes may adversely affect reproduction of walleye and smallmouth bass if these species are present. Adverse effects of acid precipitation on Wisconsin fish populations have not been documented (or studied) to date.

7. European and Canadian studies have demonstrated that lake acidification causes subtle, adverse changes in the total aquatic ecosystem before effects are observed on fish populations. No such total ecosystem studies have been conducted in Wisconsin to data.

8. The State of Wisconsin generates only about 8% of the total SO_2 and NO_x emissions in EPA Region V. Although part of Wisconsin's acid rain problem is due to local sources, it is unlikely that Wisconsin's emissions alone can account for the total acid deposition occurring in the state. To date, no studies have been performed to estimate how much of Wisconsin's acid rain problem is due to in-state emissions and how much is due to out-of-state emissions.

9. It is likely that the long-range transport of acid rain precursors, due in part to the tall stack trend, from sources as far away as the Ohio Valley, plays a significant role in contributing to Wisconsin's acid deposition problem. Similarily, air pollutants from Wisconsin may also affect the acidity of precipitation in other states. A great need exists for research that will accurately describe the long-range transport, transformation and deposition process.

10. There is a critical need for acid rain research funds. Short-term research may be funded by Department budget increases and state Legislature appropriations. But a long-term concerted research effort will require much larger grants from the federal government and contributions from utilities and other private sources.

11. Research needs in Wisconsin include expanded precipitation monitoring, watershed studies, lake studies, fish population studies, agricultural crop studies, forestry studies, and an assessment of potential economic impact.

12. Research needs nationally include modelling studies which will demonstrate how long-range transport, transformation, and deposition affect susceptible geographic areas.

13. The mechanisms for inter and intrastate coordination of acid rain activities have been established and are sufficient.

14. Action to control emissions is the most critical and urgent need we have regarding the acid rain problem. Appropriate emission controls must be established at the federal level, by implementing certain portions of the Clean Air Act, and by legislative action amending portions of the act. State authorities must aggressively enforce air quality and emission standards developed by the federal government.

15. Citizens must conserve energy as an immediate step to reduce the acid rain problem. We must also be prepared to pay now for the cost of emission control devices, or pay later with our natural and man-made resources--acidified lakes, leached soils, eroded buildings, acid groundwater--and the huge economic losses that accompany each of these.

1. EXISTING INFORMATION ON EXTENT OF ACID RAIN PROBLEM IN WISCONSIN

A. Physical-chemical Data:

Lake Monitoring

Wisconsin probably has the largest data base on lake water quality of any state in the nation. The primary data sets cover two major time periods: 1925-41 (Birge and Juday) and 1959-present (DNR Surface Water Resources Inventory, DNR Lake Monitoring Program, DNR North Central District - Environmental Protection Agency Lake Survey - Fig. 1).

In addition to these data, a number of individuals and organizations have collected lake chemistry information on a number of lakes which potentially could be incorporated into the overall data analysis for Wisconsin lakes. However, each of these data sets was collected for a different purpose, using different collection and chemical analysis methodology. Moreover, pH values collected from a single lake often vary depending on time of day, season of year, density of algae, etc.

Consequently, it is difficult to apply the data for determining long-term trends concerning lake acidification. However, cursory comparisons to data imply that Wisconsin lakes have not yet been seriously impacted by acid precipitation.

The majority of the data useable for time-trend analysis is from Vilas and Oneida Counties where most of the present lake monitoring is being conducted. Another survey of 1,000 Wisconsin lakes by the DNR Bureau of Research (Lillie and Mason, 1980) indicates that northwest Wisconsin lakes are also susceptible to acidification (Bureau of Research Report - Figs. 2 and 3).

Precipitation Monitoring (chemical)

There are no long-term chemical precipitation monitoring records for Wisconsin. The earliest major program to record pH levels of precipitation in the state was conducted by Eisenreich, et al., (1977). The stations for this study were located along the shores of Lakes Michigan and Superior. It is uncertain how transferable the data from these stations are with respect to precipitation chemistry in the interior of the state. Precipitation monitoring in Michigan has shown trends for increasing acidity in recent years. It is likely that these trends also apply to Wisconsin.

Precipitation monitoring data collected by the University of Wisconsin-Milwaukee and University of Wisconsin-Green Bay are in agreement with more recent data collected by the Department of Natural Resources in north central Wisconsin.

Precipitation monitoring was initiated in June 1979 (U. of Wisconsin-Madison, Water Chemistry) at the Department of Natural Resources, Trout Lake Station. In the fall of 1979, event-monitoring was initiated by the North Central District at several locations in and around Rhinelander. In January, 1980, the Trout Lake Station became an active NADP monitoring site. Data on the pH of precipitation from these three efforts are summarized in Fig. 4. These initial results indicate the average pH of precipitation in Vilas and Oneida Counties is approximately 4.5. Eight precipitation events collected by UW-Stevens Point from February to April, 1980 had a range of pH from 4.1 to 5.4 with a median of 4.9. The pH of precipitation was also collected in Northern Highlands State Forest from 1978 through 1979 by Pastor and Bockheim. The average pH measured was 4.0 (see section C., effect on forests). Efforts are underway to expand the precipitation chemistry data base. Starting in June, 1980, an additional NADP precipitation sampling station was installed near Spooner.

Snow Core Samples

Data on chemistry of the snowpack in north central Wisconsin were collected by three groups in 1980. M. Gage (Nicolet College) collected three replicate snow samples from each of 20 lake surfaces in February. The pH ranged from 4.2 to 4.5 with a median value of 4.4. B. Shaw (UW-Stevens Point) collected snow samples from 68 lake surfaces throughout north central and northwestern Wisconsin. These data have not been tabulated, but it appears the pH values of these samples average higher than those collected by Gage.

The largest snow core project was carried out by EPA-Duluth and the North Central District in March, 1980. Approximately 1,300 snow cores were measured at 22 sites in the field to determine the volume of water in the snow. An additional 90 bulk qualitative samples were collected to determine the chemistry of the snowpack. The analysis is still in progress but the available data indicates most of the samples had a pH less than 5.0 with a low value of 4.4.

While definite conclusions regarding the chemistry of the snowpack cannot be stated until completion of the analysis, indications are that cumulative snowpack is slightly less acidic than the pH of individual precipitation events, but still more acidic than normal rainfall which has a pH of 5.6.

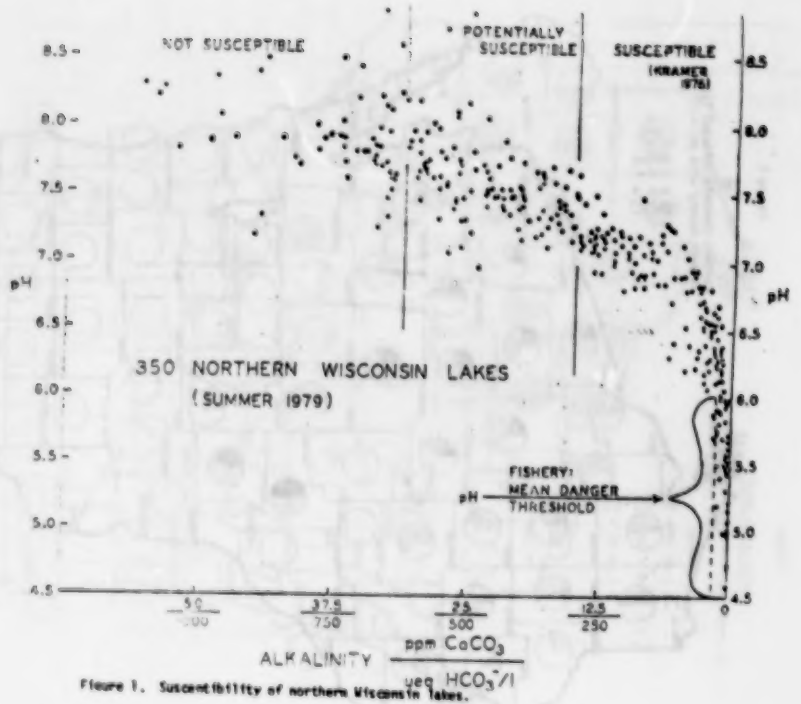


Figure 1. Susceptibility of northern Wisconsin lakes.

Figure 2.

pH

Percent randomly selected lakes in each county with pH:

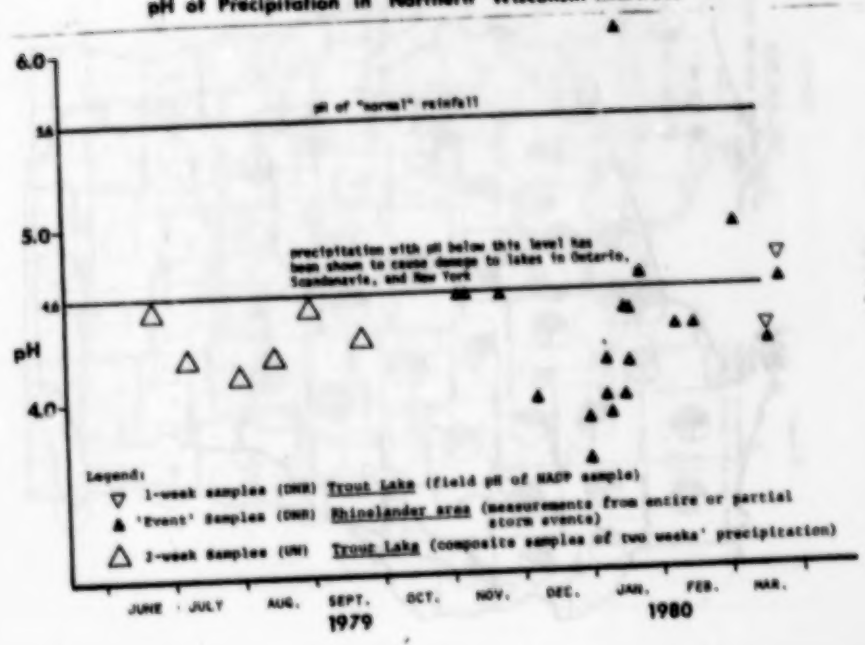
< 6.0
> 6.0, < 7.0
> 7.0

Figure 3.

TOTAL ALKALINITY
Percent randomly selected lakes in each county with:
≤ 15 mg / l
> 15 - 30 mg / l
> 30 mg / l

FIGURE 4

pH of Precipitation in Northern Wisconsin (DNR & UW)



6. Susceptibility of Aquatic Systems:

Characterization of Lakes by Type

Limnologists in Wisconsin have long since divided lakes into seepage lakes (those without inlet or outlet streams) and drainage lakes (those with a surface inlet or outlet). The lakes in the northern half of Wisconsin are approximately equally divided between seepage and drainage lakes. Seepage lakes in poorly buffered soils tend to be more acidic than drainage lakes. The difference in lake chemistry between the two lake types is caused by the degree of watershed influences on lake recharge. Some of the seepage lakes are "acid bog lakes" with low pH due to long-term successional changes. Separating acidification due to the normal process of succession from the more recent phenomenon of acid rain may present a major problem in Wisconsin due to the existence of large numbers of both lake types.

Soils

The soils of northern Wisconsin (Fig. 5) reflect the parent material from which they were derived and are, therefore, acidic. The soils are primarily sandy and sandy-loams with relatively high permeability and low buffering capacity. The other major group of soils are the peatland soils which are very acidic as a result of the plant communities associated with these soils.

Bedrock Geology

The bedrock geology of north central Wisconsin (Fig. 6) is dominated by the massive Precambrian shield composed of granite and other highly insoluble igneous rocks. The northwestern portion of Wisconsin is underlain by sandstones which are more permeable, but like the igneous rocks, contain little calcium or magnesium carbonates to buffer acid precipitation.

Surficial Geology

The surficial geology of northern Wisconsin (Fig. 7), rocks located between the soils and the bedrock, consists of tills derived from at least four different glacial periods. This material is quite heterogeneous. In some locations, small amounts of calcareous materials (high in buffering capacity) deposited by the glaciers are found interspersed among larger amounts of material having very low buffering capacity. The rate of groundwater flow is also determined to a major extent by the distribution of the different glacial tills. The complex and varied nature of the surficial geology in part explains the striking contrast in susceptibility of various lakes located over the Precambrian shield bedrock.

In general, lakes in the northern portion of the state contain approximately 10 to 20 milligrams per liter (mg/l) total alkalinity. This is one order of magnitude lower than lakes located in the southern portion of the state. Those seepage lakes in northern Wisconsin which have very little contact with the groundwater often contain only trace amounts of neutralizing material making them extremely susceptible to acidic atmospheric deposition.

Groundwater

The groundwater quality of north central Wisconsin is related to the geology and soil characteristics of the area. Generally speaking the groundwater is soft, with total alkalinities often less than 50 mg/l (Wisconsin DNR Publication, 1970). Those lakes in northern Wisconsin recharged by groundwater receive a continued supply of buffering agents, but the amount is relatively small. The chemical nature of groundwater in this area is further evidence of general acid deposition susceptibility in north central Wisconsin.

C. Effects on Flora and Fauna

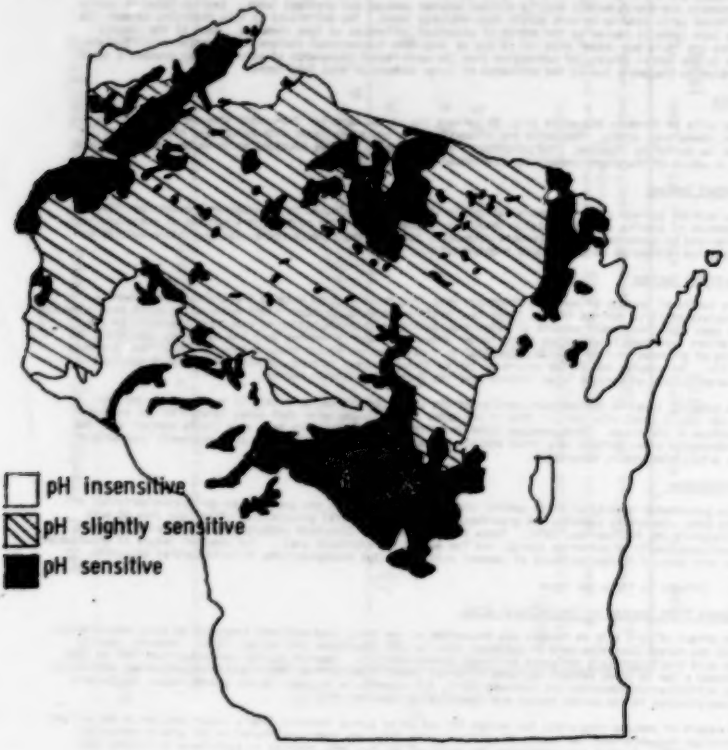
Forest Plant Species and Agricultural Crops

An effect of acid rain on forests was documented at the First International Symposium on Acid Precipitation and the Forest Ecosystem held at Columbus, Ohio in 1975 (Dochinger and Seliga, 1976). However, reports on acid precipitation's influence on forest growth conflict. Swedish studies conducted from 1896 to 1965 showed a two to seven percent decrease in forest growth from 1950 to 1965. Growth reduction was attributed to acidification (Johnsson and Sundberg 1972), but attempts to document forest growth losses due to acid precipitation in the United States are inconclusive (Cowling 1979).

A report of reduced ring width for balsam fir and white spruce downwind from a copper smelter at White Pine, Michigan suggests that low levels of sulfur dioxide (SO_2) may have contributed to the growth reduction (Gordon 1978). Ambient air containing low levels of SO_2 has been reported to contribute to reduced seed and pollen production in eastern white and red pine (Houston and Dochinger 1977).

Acid precipitation damage to vegetation in Wisconsin is not documented, but sulfur dioxide injury has been reported (Rowlund, 1973, Tibbitts et al. 1977). Laboratory studies have confirmed that white pine from selected areas in Wisconsin developed needle necrosis (browning) after being fumigated with 0.05 ppm SO_2 for six hours (Houston 1974).

Figure 5 Susceptibility of surface mineral soil by soil region in Wisconsin to change in pH by acid precipitation



J. G. Bockheim, UW-Madison, 1980

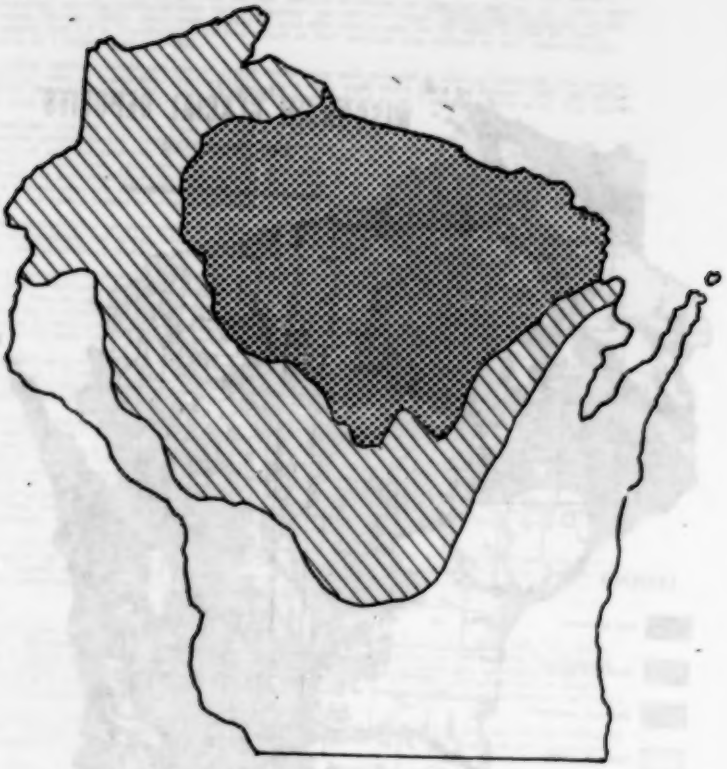


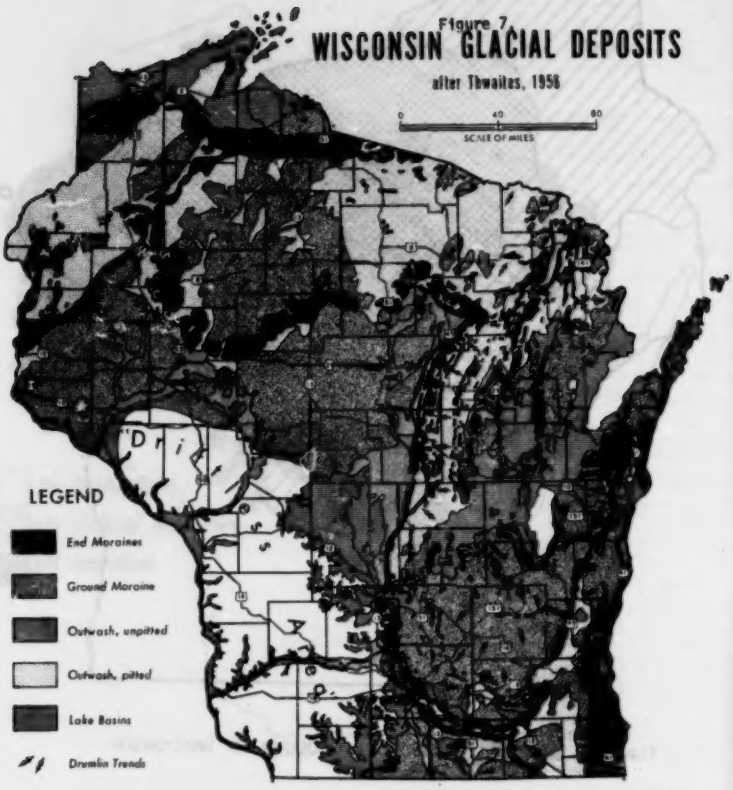
Figure 6. GENERALIZED BEDROCK GEOLOGY OF WISCONSIN

Igneous Sandstone Limestone

Figure 7

WISCONSIN GLACIAL DEPOSITS

after Thwaites, 1956



University of Wisconsin

Wisconsin Geological and Natural History Survey

George F. Hanson, Director and State Geologist

Direct and indirect damage to forest and agricultural crops has been demonstrated with simulated acid rain applied in laboratory, greenhouse and field experiments. Simulated rain acidified with sulfuric acid at a pH of 3.2 eroded waxes from the leaf surfaces of willow oak (Quercus phellos) and kidney bean. Simulated rain also inhibited bean rust development and the rust fungus (Cronartium fusiforme) on oak leaves (Shriner 1976). Bush beans exposed to acid mist once a week for six weeks at five pH levels ranging from 5.5 to 2.0 displayed visible injury on leaf surfaces when exposed to mist concentrations below pH 3 (Hindawi, et al. 1980).

In other studies visible symptoms of tissue damage have been produced by misting simulated acid rain at pH 3 or lower on kidney bean (Shriner 1977), pinto bean, sugar maple (Wood and Bormann 1975) and yellow birch (Wood and Bormann 1974). But seed pod growth was reduced at pH 3 and above with no visible symptom on bush beans (Hindawi, et al. 1980).

Simulated rain has also been shown to inhibit bacterial nitrogen fixation on the roots of bean and soybean plants (Shriner 1976). Soil-plant relationships have also reduced nitrogen uptake within the roots of sweetgum seedlings (Haines and Best 1976) and inhibited root-knot nematodes in soil (Shriner 1976). In addition, simulated acid rain has been shown to inhibit leaf litter decomposition in the forest and accelerate nutrient leaching from the forest floor. Norway spruce (Picea abies) seed germination was reduced when the soil pH was lowered to 4.0. However, Scotch pine (Pinus sylvestris) seed at a soil pH of 4.0 to 4.6 showed no effects (Abrahamsen, et al. 1976).

Acid precipitation has been shown to induce "russetting"--brown blemishes-- that cosmetically ruin Yellow Delicious apples for market. Precipitation with an approximate pH of 4.0 caused by volcanic activity in the Kona District of Hawaii reduced tomato production (Kratky et al. 1974).

Acid precipitation containing sulfur may be beneficial to vegetation. Sulfur-deficient alfalfa plants grown in a Madison, Wisconsin greenhouse from January to May 1971 obtained as much as 73 percent of their sulfur from the atmosphere (Hoeft et al. 1972). From 1971 to 1979 in Wisconsin, an analysis of sulfur contained in alfalfa and the soil in which the crop was growing indicated average plant sulfur levels totaled slightly above the level needed for optimum growth, except in 1977 and 1978. Average soil tests for sulfate were low or deficient except in 1977 (Lloppi and Kaehler 1980).

Simulated acid rain has been shown to increase the growth of white pine seedlings (Wood and Bormann 1977). In a 20 week study the best growth of white pine was obtained at pH 2.3, suggesting that acid rain may increase nitrogen uptake. If the study were continued for a longer time, direct injury to the seedlings could have occurred.

Acidity created by adding fertilizer to agricultural soils in the United States appears to have more of an impact on soil chemistry than acid precipitation (Tamm 1976). Agricultural limestone is often used to correct soil acidity. Acid precipitation may have a greater effect on unmanaged or forest soils (Cowling 1979) by depleting nutrients needed for plant growth. But Pastor and Bockheim (1980) investigations of a mature, aspen-mixed hardwood stand in Vilas County, where precipitation pH averaged 4.0 during 1978-1980, showed that sulfate was the dominant form of sulfur detected and highly correlated with the pH of incoming precipitation. The forest canopy's leaf and bark surfaces absorbed 44 percent of the incoming acidity. The study indicates that possible pH declines in northern Wisconsin lakes may be due to the direct addition of hydrogen ions from acid deposition rather than from groundwater.

EPA's Corvallis Environmental Research Laboratory is trying to determine acid precipitation effects on a variety of agricultural crops grown under field conditions (EPA 1979). The agency is using selected sites located near current acid deposition monitoring stations in the study. Results may provide a better understanding on how acid precipitation could affect crop yield.

Fish

Fish and other aquatic life have a relatively wide pH tolerance, from 5.5 to 9.5 (AFS, 1979; U.S. EPA, 1977). Detrimental metabolic, respiratory, and reproductive changes occur in fish outside the threshold range of 6.0 to 9.0. The normal unpolluted rainfall pH level of 5.6 is within the tolerable range for fish. However, since rainfall can acquire a much lower pH from air pollution, the chemistry of waters receiving acid rain may change enough to affect fish. The pH of precipitation downwind from air pollution sources has been recorded as low as 2.4.

The effects of low pH are illustrated by the problems associated with coal mine drainage in coal producing states. Streams receiving acid wastes are sometimes clear but barren of life. Improved pH's downstream are accompanied by greater diversity.

Many lakes in northern Wisconsin have pHs which are presently within the tolerable range for fish, but some approach or exceed the lower threshold. Bush (1980) reported 2,700 Wisconsin lakes having a pH less than 6. Most of these are small seepage lakes with small drainage areas. In such circumstances, continued acid precipitation could have a greater impact on these seepage lakes than in drainage lakes with larger watersheds, greater groundwater contributions and greater quantities of dissolved materials.

Beamish (1976) reported that reproduction of various species of fish is affected at pH ranges of 4.5-6.0. Walleye (Stizostedion vitreum) and smallmouth bass (Micropterus dolomieu) are most sensitive (pH 6.0), while the yellow perch (Perca flavescens) has the greatest tolerance, to as low as 4.5. The findings of Beamish are shown in Table 1.

Table 1. Approximate pH at which fish in the La Cloche Mountain Lakes, Ontario, stopped reproduction (after Beamish, 1976).

pH	Species
6.0+ to 5.5	Smallmouth bass *Micropterus dolomieui*
	Walleye *Stizostedion vitreum*
	Burbot *Lota lota*
5.5 to 5.2	Lake trout *Salvelinus namaycush*
	Trout-perch *Percopsis omiscomaycus*
5.2 to 4.7	Brown bullhead *Ictalurus nebulosus*
	White sucker *Catostomus commersoni*
	Rock bass *Ambloplites rupestris*
4.7 to 4.5	Lake herring *Coregonus artedii*
	Yellow perch *Perca flavescens*
	Lake chub *Couesius plumbeus*

The fathead minnow (Pimephales promelas) is commonly used as a test organism for environmental stress. Mount (1973) reported that at pHs 4.7 and 5.2 behavior was abnormal and the fish were deformed. At pH 5.9 egg production and hatchability were reduced. In contrast brook trout eggs hatched at pH 4.65, but survival was reduced compared to eggs hatched at higher pH (Trojnar, 1977). This evidence suggests that when pH drops below 6.0 there is reason for concern and adverse effects may be expected.

Fish welfare is highly dependent upon the availability of food resources. If pH changes affect the food resource, a corresponding effect would be expected in the fish population. Studies indicate that the diversity of food species is reduced as pH is lowered. The effect of decreasing pH on various forms of aquatic life is reported in Table 2.

Low pH waters have the potential for dissolving heavy metals such as aluminum, copper, zinc, nickel and mercury. Some of these heavy metals are toxic to fish, but to date no evidence of mortality attributable to acid rain has been observed in Wisconsin. Metals of concern in the natural environment are aluminum, copper, zinc and nickel. However, even low quantities of dissolved mercury in some forms although perhaps not causing direct mortalities, have been known to accumulate in fish flesh in sufficient quantity to render fish unacceptable for marketing (FDA, 1974). A mercury level of 0.05 micrograms per liter has been selected as a water quality criterion (EPA, 1977). For a review of selected literature regarding effects of acid rain on fish refer to Fish Management Report 108 available from the Department of Natural Resources, Madison, Wisconsin.

Other Aquatic Biota

The most conspicuous effects from acidification of freshwaters are observed in fish, however, equally as serious but less conspicuous are the effects of acidification on microdecomposers, algae, aquatic macrophytes, zooplankton and zoobenthos. Because an aquatic ecosystem is extremely complex, a total ecosystem study is often very expensive. There are very few studies in Wisconsin that have examined all the components, and therefore it is difficult to ascertain what effect acid deposition may have, in total, on a given lake. At this time we must assess the effects of acidification by review of the literature.

In lakes that have been impacted by the process of acidification, bacterial activity has apparently decreased. The inhibition of specific biochemical processes at low pH has resulted in the overall reduction of decomposition. Several observations of acid lakes have shown an abnormal accumulation of coarse organic detritus on the bottom. The growth and productivity of aquatic macrophytes have been reduced by 70 percent at pH 4 and the period of flowering has been delayed 10 days. Acidophilic mosses such as Sphagnum increased dramatically when the pH of Lake Orvattnet, Sweden, decreased 0.8 units to approximately 4.0 (Almer, 1974).

Phytoplankton investigations in lakes of Sweden, Norway and Canada indicated the greatest change in species composition occurred in the pH interval 5-6. Phytoplankton in acid lakes are dominated by a few species and exhibit a reduced biomass and productivity.

Zooplankton analyses of acidified lakes have shown limitation of many species and simplification of the zooplankton communities. When fish and zooplankton were each correlated with the same limnological variables in an Ontario study, pH was found to be the major determinant of these communities.

Surveys in Sweden, Norway and North America have shown that acid waters have fewer species of benthic invertebrates than localities which are less acidic. In examining 632 lakes in Scandinavia, snails were absent at pH values below 5.2 and occurred less frequently in the pH range 5.0-6.0, when compared to more neutral or alkaline waters.

The tolerance of aquatic invertebrates to low pH varies over their life cycles. Adult insects at the time of emergence appear to be particularly sensitive to pH levels of less than 5.5. In a Canadian study (Malley, 1980) crayfish suffered mortality when they were in postmolt stages at a pH of 4. Postmolt crayfish held at a pH of 5.0 showed slower progression of molt cycle stages and of calcification of the exoskeleton than individuals held at a pH 6.0.

Although the effects of acidification are most apparent in the fishery of an impacted lake, the entire ecosystem is actually being stressed. The ecosystem components are all mutually dependent; therefore the effect of individual stress ultimately appears throughout the entire system.

Terrestrial Animals

Very little information exists with regard to the effects of acid deposition on terrestrial animals. The major acid deposition-specific studies which seem to have been done to date deal with salamanders in the northeastern United States (Pough, 1976 and 1977) and soil micro-organisms in Norway (Schofield, 1980). In addition, some reports have mentioned potential acid deposition-related secondary effects, such as possible decreases in aquatic macrophyte forage affecting moose populations, and diminishing aquatic insect populations having similar effects on insectivorous birds (Galloway et al. 1978). Work of perhaps indirect importance has also been done with respect to the effects of the acid deposition precursors, such as sulfur dioxide and nitrogen oxides on both beneficial and pest species of insects (see Glass, 1979). Only the salamander investigations will be discussed here.

TABLE 2. SUMMARY OF EFFECTS ON AQUATIC ORGANISMS WITH DECREASING pH

8.0-6.0	• Long-term changes of less than 0.5 pH units in the range 8.0 to 6.0 are likely to alter the biotic composition of freshwaters to some degree. The significance of these slight changes is, however, not great.
	• A decrease of 0.5 to 1.0 pH units in the range 8.0 to 6.0 may cause detectable alterations in community composition. Productivity of competing organisms will vary. Some species will be eliminated.
6.0-5.5	• Decreasing pH from 6.0 to 5.5 will cause a reduction in species numbers and, among remaining species, significant alterations in ability to withstand stress. Reproduction of some salamander species is impaired.
5.5-5.0	• Below pH 5.5, numbers and diversity of species will be reduced. Many species will be eliminated. Crustacian zooplankton, phytoplankton, molluscs, amphipods, most mayfly species, and many stone fly species will begin to drop out. In contrast, several pH-tolerant invertebrates will become abundant, especially the air-breathing forms (e.g., Gyrinidae, Notonectidae, Corixidae), those with tough cuticles which prevent ion losses (e.g., Sialis lutaria), and some forms which live within the sediments (Oligochaeta, Chironomidae, and Tubificidae). Overall, invertebrate biomass will be greatly reduced.
5.0-4.5	• Below pH 5.0, decomposition of organic detritus will be severely impaired. Autochthonous and allochthonous debris will accumulate rapidly. Most fish species will be eliminated.
4.5 and below	• Below pH 4.5, all of the above changes will be greatly exacerbated, and all fish will be eliminated. Lower limit for many algal species.

A summary of the biological structure in bodies of freshwater at various pH values (Katz 1969).

Range	Warm Water Species	Cold Water Species	Benthos	Microorganisms	Algae	Plants
6.5-7.0	Full fish production	Full fish production	Relatively normal, molluscs occur commonly	Small numbers of fungi; various bacterial species occur; microflora quite normal	Essentially normal	Normal flora
6.0-6.5	Maintenance and growth	Full fish production				
5.5-6.0	Maintenance but no carry-over	Maintenance and growth	Diverse fauna of benthic organisms; number of different species. Blackflies, mayflies and stoneflies are present in numbers	Yeasts and Thiobacillus-Ferrobacillus bacterial group are important; bacterial species diversity decreases	Diatoms, Flagellates, and green algae are common; Oscillatoria may be found, only blue-green algae commonly occurring at pH lower than 7.0	Most aquatic plants will grow at this range if substrate, water velocity and fluctuations are satisfactory
5.0-5.5	No viable fishery	Maintenance but no carry-over				

Acid deposition may affect amphibians because they lay their eggs in temporary snow melt and rainfall runoff ponds. In the northeast a significant number of these ponds may be highly acidic because the precipitation runoff which forms them has not yet interacted with soil-related or other buffering agents.

Pough found that where breeding ponds were near neutrality (pH 7) the spotted salamander (Ambystoma maculatum) had less than 1% egg mortality, while in ponds with higher acidities (pH 5.0 to 4.5) mortality was greater than 65%. Because the number of abnormally acidic breeding ponds in the northeast is probably high, the spotted salamander appears to be in some danger. Moreover, since one-third of the salamanders and half of the frogs and toads in the United States breed in these types of ponds, other species might also be threatened (Glass cites two additional reports which discuss the effects of highly acid waters on frogs and toads in New Jersey and frogs in England). Because many of these species play important roles in food webs, both as predators and as food sources, the ecological implications of a reduction in amphibian populations could be serious.

D. Effects on Material Objects:

Stone and Metal

Documentation on corrosion of stone and metal from acid deposition is scarce--particularly in the United States where relatively new structures have not been exposed to weather and air pollution as long as materials in other countries. However Tschirhart (1980) estimates that degradation of material objects in the eastern U.S. results in a $13 billion loss annually.

Likens, Bormann and Johnson (1972) claim that the average pH of rainwater in the Rhine-Ruhr industrial area of West Germany has dropped from about pH 5 to less than pH 4 in the years between 1956-1966. This may be partially supported in the same region by Winkler (1973), who used time-lapse photographs of a calcite-cemented sandstone castle to demonstrate the near exponential rate change in weathering of stone monuments. A 1908 photograph shows that features of statues on the castle, which was built in 1702, were still intact. But by 1968, as the second photograph shows, features were completely obliterated.

Another set of photographs illustrating stone figures on building relief dating from 1170 in the same West German region shows similar damage. Destruction was severe by 1900 after 600 years of exposure, but has become much worse within the last 80 years.

In both cases, it is suspected but inconclusive that acid deposition may have been at least partially responsible for damaging the stone.

Current Research

To discover whether acid precipitation is eroding statuary and other stone structures in the United States, EPA is studying marble headstones and markers placed nationwide by the Veteran's Administration. Since an 1875 Act of Congress, the VA has provided over 2,500,000 tombstones to various national cemeteries. The tombstones are carved in only a few basic shapes and are made from stone taken from only three quarries. EPA has selected cemeteries in the Appalachian region, far west and northeast to look for measureable loss of detail, rounding of edges and surface erosion on the tombstones. Damage estimates will then be correlated with data on the stone's history found in VA, air pollution and meteorological records.

EPA cautions, however, that evaluating field data and correlating it to pollution levels will be very difficult because of the many variables associated with material damage to minerals.

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2. EXISTING INFORMATION ON THE ACID RAIN PROBLEM IN THE EASTERN UNITED STATES

A. Regional Precipitation Data:

Over the past decade a number of researchers have reported an increase in the acidity of precipitation falling east of the Mississippi River. Some evidence also indicates that increased dry deposition of primarily sulfates and nitrates in the same region contributes additional acidity.

Gene Likens of Cornell University has been investigating both the strength and geographical extent of acid deposition since 1963. While his most concentrated studies have been conducted in New York and New Hampshire, he and various other workers have also determined the geographical range of acid deposition in eastern North America.

Studies conducted at Hubbard Brook Experimental Forest, New Hampshire, revealed that weighted (for amount of precipitation) annual averages of precipitation pH for the years between 1964 and 1974 varied from 4.0 to 4.2 (Likens, et al. 1974, 1976, 1976a; Cogbill and Likens, 1974). For a given rainfall event, the lowest recorded pH was 3.0. These values are obviously many times the natural rainfall acidity of 5.6. Sulfuric acid (H_2SO_4) was the predominant acid found at Hubbard Brook, with nitric acid being next in abundance. Likens also found that the annual hydrogen ion (H^+) concentration in rainfall increased by 30% during the decade of measurement. The volume of precipitation affected this increase to some extent, but chemical effects also played an important role, with nitric acid making the greatest contribution to the increase.

Investigations by Likens and others in New York and other locations throughout the northeastern United States have produced similar results. Precipitation pH measured at several sites in the Finger Lakes area in New York State appears to be at the same level as that in New Hampshire. In addition, workers in New England reported the following weighted annual average pH values: New Durham, New Hampshire - 4.3, Hubbardston, Massachusetts - 4.3, and Thompston, Connecticut - 4.3. At New Haven, Connecticut samples of there at Killingsworth, Connecticut in April, 1970 averaged 4.3 (Likens, et al. 1972). Finally, a collected in the spring and summer of 1970 had an average pH of 3.8, while values recorded 30 miles east study conducted for several small streams in the Pinelands of New Jersey in 1970-72 and 1978-79 discovered pH levels of approximately 4.0 (Johnson, 1979).

Deposition monitoring studies in Canada show that the eastern portion of that country is subject to the same levels of precipitation acidity as the northeastern United States. One study, which measured deposition throughout Canada, found that southern Ontario and the Great Lakes Basin had the highest concentrations of sulfates (2 to 7 ppm) and nitrates (1 to 6 ppm) in the nation, and that the "general pH level" in the region was between 4 and 5, with levels of below 4 having been detected (Summers and Whelpdale, 1976). Another study, done in the Maritime Provinces, revealed similar precipitation pH levels (Shaw, 1979).

Precipitation monitoring undertaken in the upper Midwest indicates generally, though not uniformly, more moderate pH levels than those found in the East. Researchers in Michigan measured pH at 60 sites statewide between September, 1972 and December, 1974 and reported a weighted average annual pH of 5.0. As might be expected, the northern portions of the state had the highest readings (lowest acidity) and the southern and eastern areas, where the greatest population and most industrial centers are found, had the lowest readings (highest acidity) (Richardson and Merva, 1976). The study concluded that abnormally high precipitation acidity in some areas of the state could cause problems locally.

In central Illinois, a one-site study from May, 1977 to February, 1978 discovered an average precipitation pH of 4.1. This is compared to a calculated pH of 5.9 for the same site in 1954. The cause of this change in pH over time has not been firmly identified (Stensland, 1979).

In Iowa, rainfall monitored by a study done at six sites across the state from 1971 to 1973 was found to contain virtually no excess acid. Sample pH values varied between 5.8 and 6.5 with an overall average of 6.2 (Tabatabai and Laflen, 1976).

The situation is not so easily discernible in Minnesota. Monitoring conducted at Marcell, in northeastern Minnesota, from July, 1978 to January, 1980 indicates abnormally high acidity levels in precipitation at that location. This study, which is ongoing as part of the National Atmospheric Deposition Program (NADP), reports that of 59 precipitation samples taken during the 1978-80 period, 85% had pHs lower than the natural 5.6 level, 53% had pHs lower than 4.6, and 25% had pHs lower than 4.0 (NADP data, 1980). These high levels of acidity are comparable to those reported for the northeastern United States. On the other hand, studies by various other researchers for the Boundary Waters Canoe Area and nearby locations, again in the northeastern part of the state, report mean precipitation pH levels ranging from 5.6 or 5.7 down to 4.8 (Glass, 1979). The later investigations (late 1970's) tend to find lower pH levels (higher acidity) than the earlier ones (early to mid 1970's), but no clear trend is apparent.

From studies such as those discussed and early reports, Likens et al. (1979) and Cogbill (1976) have mapped both the current and historical geographical extent of acid deposition in eastern North America. As the accompanying figure shows, (Fig. 8) there appears to have been a westward and southern expansion of acid deposition since the earliest widespread measurements were taken in 1955-56.

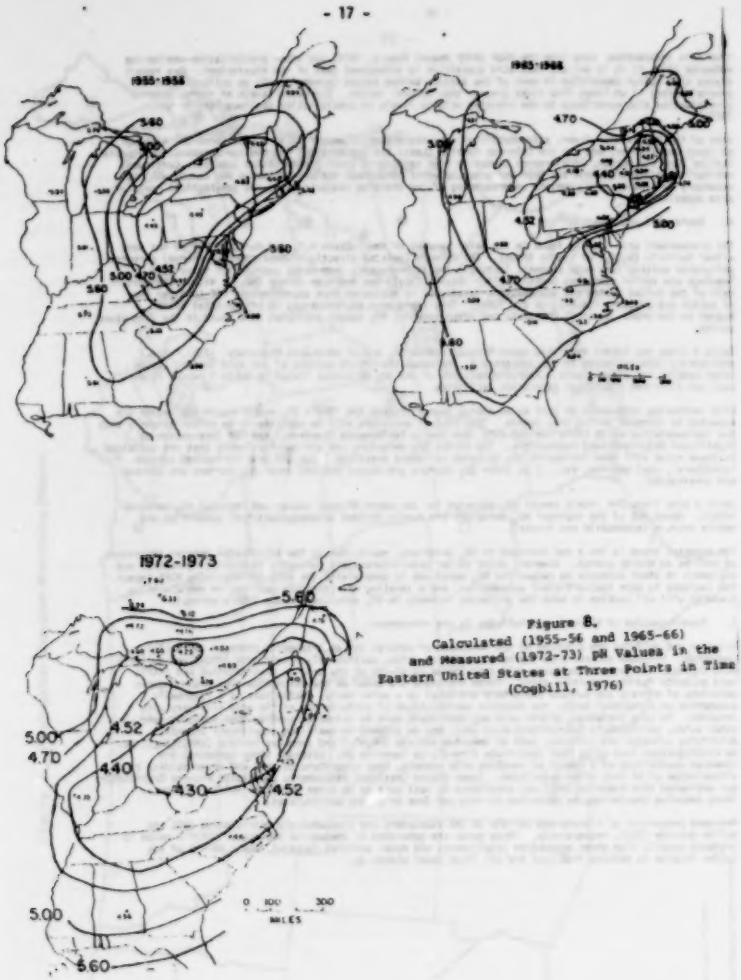

Figure 8.
Calculated (1955-56 and 1965-66) and Measured (1972-73) pH Values in the Eastern United States at Three Points in Time (Cogbill, 1976)

From this information, data from the NADP (NADP Annual Report, 1979) and other precipitation-monitoring networks (Fig. 9) it is evident that acid deposition is widespread east of the Mississippi. One report states that sulfur deposition in most of the eastern United States (predominantly as sulfuric acid in precipitation) is at least five times greater than natural levels. Increased levels of nitric acid in precipitation also contribute to the elevated acidity levels in precipitation (Galloway and Parker, 1979).

West of the Mississippi River, acid deposition does not presently appear to be a major problem, although at least two studies, one for the Colorado Rockies (Lewis and Grant, 1980) and one for Pasadena, California (Liljestrand and Morgan, 1978) report unusually high acidity in local precipitation samples. Continued monitoring information from the NADP and other networks throughout the United States and Canada will be necessary to provide more complete understanding of the changing concentrations and geographical range of acid deposition.

B. Regional Sources Data:

The predominant acid loading found in the water samples of the Eastern U.S. and Northern Europe has been either Sulfuric (H_2SO_4) or Nitric (HNO_3). The primary (emitted directly without chemical change) airborne pollutants emitted from both biogenic (natural) and anthropogenic (man-made) sources for these acid loadings are sulfur compounds (mostly sulfur dioxide (SO_2)) and nitrogen oxides (NO_x). Within the eastern half of the United States and southeastern Canada, it is estimated that approximately 200 tons per year of sulfur are biogenic (Lavery, et al. 1979). This represents approximately 2% of the total sulfur budget in the area. No total (biogenic and anthropogenic) NO_x budget estimates were found in the literature survey.

Table 3 lists the latest available upper Midwest states SO_2 annual emissions (accuracy: ±2%). The preliminary data collected in the eastern U.S. indicates that 60-70 percent of the acid loading in the water samples is sulfuric acid. Approximately 90% of the SO_2 emissions listed in Table 3 result from coal and oil-fired electrical generation facilities.

With increasing dependence on coal as an energy source through the 1980's SO_2 emissions in the region are expected to increase during this decade. This rise in emissions will be expected to be offset slightly with the implementation of US EPA's revised NSPS (New Source Performance Standards) and PSD (Prevention of Significant Deterioration) regulations. The strict SO_2 emissions and air quality levels that are contained in these rules will mean increasing SO_2 emission abatement practices (flue gas desulfurization systems (scrubbers), coal washing, etc...) as older SO_2 sources are phased out and newer SO_2 sources are planned and constructed.

Table 3 also lists the latest annual NO_x emission for the upper Midwest states and regional NO_x emission totals. About 80% of the regional NO_x emissions are evenly divided between electrical generation and mobile sources (automobile and trucks).

The expected trend is for a net increase in NO_x emissions, mostly due to the anticipated greater dependence on coal as an energy source. However, major boiler manufacturers are currently incorporating methods and equipment in their products to reduce the NO_x emissions to comply with the NSPS for NO_x. The NSPS impact, the increase in more fuel-efficient automobiles, and a leveling off (possible decline) in vehicle miles traveled will all combine to make the projected increase in NO_x emissions in the 1980's modest.

C. Transformation of Nitrates and Sulfates in the Atmosphere:

Nitrates and sulfates are produced by the oxidation of natural and anthropogenic nitrogen and sulfur compounds. Nitrates and sulfates may be generated as acids, particularly nitric acid (HNO_3) and sulfuric acid (H_2SO_4). In general, sulfuric acid contributes to 60-70% of the acid in precipitation and nitric acid accounts for the remaining third. These fractions are based on the assumption that anthropogenic emissions of nitrate and sulfate precursors are equal on a molar basis. While this is a reasonable assumption on a regional basis, the relative contributions of sulfuric and nitric acid will vary with location. In some instances, nitric acid may contribute more to rainwater acidity than sulfuric acid. Other acids, particularly hydrochloric acid (HCl) may be present in small but significant amounts. Acidifying nitrates and sulfates, such as ammonium nitrate (NH_4NO_3) and ammonium sulfate ($(NH_4)_2SO_4$), may be distinguished from acids that contribute directly to lowering pH. Although these compounds are somewhat neutralized as a result of reacting with ammonia, they contribute to soil and water acidity by dissociation of H+ ions after deposition. James Gibson (National Atmospheric Deposition Program Coordinator) has estimated that ammonium (NH_4^+) may contribute to soil acidity 1½ times more than sulfur compounds. These ammonium species may be deposited in rain and snow or as dry particulates.

Man-made precursors of nitrate and sulfate in the atmosphere are predominately nitric oxide (NO) and sulfur dioxide (SO_2), respectively. These gases are generated by combustion processes. Nitric oxide is produced equally from power generation (stationary) and motor vehicles (mobile), while 80-90% of the sulfur dioxide is emitted from coal and oil fired power plants.

Figure 9. Precipitation Chemistry Monitoring Stations

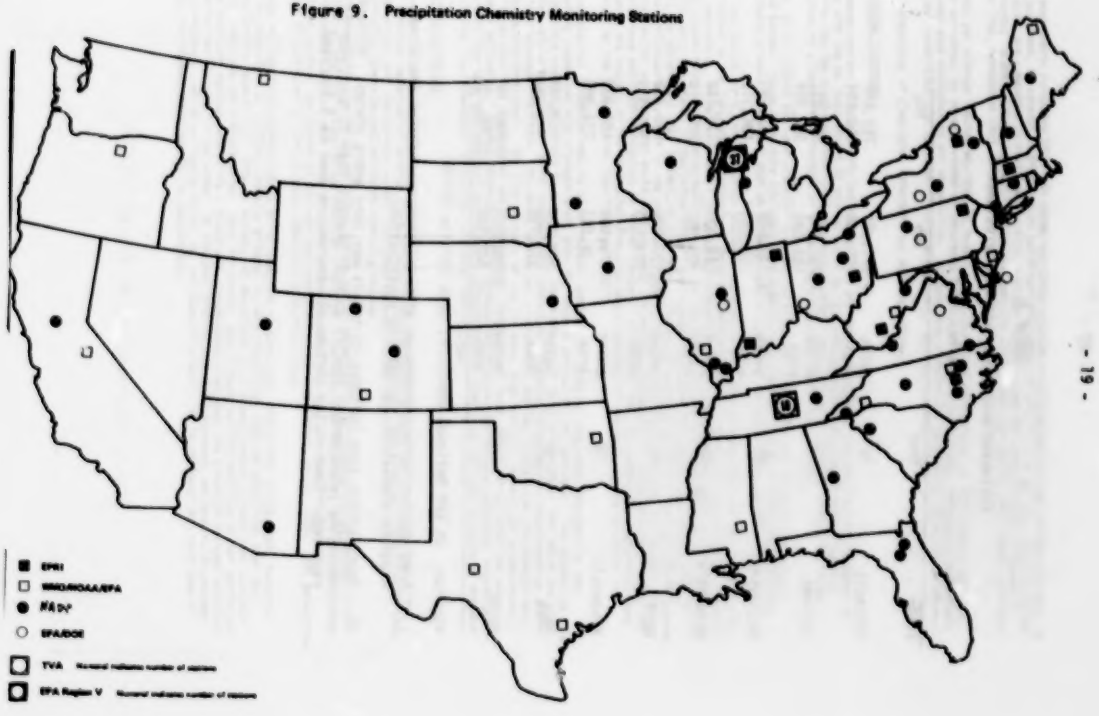

Table 3.

Estimated Annual SO_2 and NO_x Emissions(a)

Tons Per Year

State	Year		SO_2	NO_x
Illinois	79	point	1,811,691	765,818
		area	95,398	512,965
Indiana	77	point	1,733,848	639,831
		area	196,695	322,359
Michigan	75	point	1,172,848	335,960
		area	51,953	406,313
Minnesota	77	point	255,302	112,148
		area	29,567	229,516
Ohio	77	point	3,131,221	684,432
		area	128,513	502,579
Wisconsin	78	point	679,499	188,832
		area	38,642	215,865
Iowa	78	point	318,435	163,766
		area	313,750	116,494
TOTAL		Point	8,902,844	2,890,787
		Area	500,768	2,306,081

(a)Source: US EPA National Emissions Data Service (NEDS)

1) Area sources include estimates of transportation related emissions based on population and vehicle registration.

2) Point source size included in totals may vary among states. National reporting requirements specify sources greater than 25 tons/year be reported. Some states include all sources or down to 1 ton/year.

The stoichiometric oxidation of nitric oxide and sulfur dioxide to nitrate and sulfate species may occur in the gas phase, in aqueous droplets or on solid particles (Fig. 10 and 11). In general, these oxidation processes are dependent on relative humidity, sunlight intensity and the concentrations of potential reactants: ammonia (NH_3), ozone (O_3), hydrogen peroxide (H_2O_2), hydroxyl radical (OH), metal catalysts (iron (Fe), manganese (Mn), vanadium (V)) and initial concentrations of SO_2 and NO.

Sulfate and nitrate species may then be incorporated onto other particulates or into aqueous droplets, after oxidation, by physical-chemical processes such as absorption, adsorption, homogeneous nucleation, heterogeneous condensation and coagulation. Sulfates and nitrates are then deposited to earth, snow or fog [wet deposition] and as gases or particulate matter [dry deposition].

D. Meteorology of Long-range Transport and Acid Deposition:

Long-Range Transport

In remote regions of Scandinavia and the New York Adirondack Mountains, the ever-increasing number of lakes with low pH (less than 5.0) and little or no fish combine with knowledge of prevailing wind patterns and the previously-mentioned increase in fossil fuel burning to strongly infer long-range (hundreds of kilometers) transport of airborne acid precursors into these regions.

Lyons, et al. (1976) has used satellite pictures to track two sulfate aerosol plumes in the eastern United States. These plumes were tracked for several days, lending support to long-range transport hypothesis of acid precursors such as sulfates, which have long residence times (several days).

Over the last 25 years, two pollution abatement strategies and types of equipment may have inadvertently contributed to the long-range transport of gases and aerosols, some of which may be considered airborne acid precursors. To mitigate local air pollution problems and help maintain air quality standards, taller stacks have and are being built to allow for the removal of the effluent far away from the source. In 1980, only two stacks in the United States were higher than about 180 meters, now essentially all stacks are taller than that (Lihans, et al. 1979). The use of particulate control devices (90-99 percent removal efficiencies) result in the gases and primary (in-stack formation) aerosols having much fewer adhesion nuclei on which they would fall out near the source. Consequently, large amounts of gases and aerosols have additional potential to travel farther. Pollutants that are eventually transported long distances are subject to the horizontal direction shear (change) of the wind, as the pollution is "steered" by the flow patterns (the "prevalent wind").

A meteorological situation that is of particular interest in terms of long-range transport to the stagnant or somewhat high pressure areas over the eastern portion of the continent. The stagnation of a high pressure system can result in a large area (particularly in large urban areas) into which the highly reactive acid precursors are being "pumped" and subject to primarily photochemical transformation and some heterogeneous reactions. The whole system has a relatively shallow mixing layer and advects very slowly east-northeastward. The slow movement of the air mass, high moisture content and predominately clear skies favor the homogeneous and heterogeneous formation of large amounts of sulfates and other secondary pollutants. These clockwise-rotating systems, which occur year around, sometimes become so large that they have the potential to transport pollutants from sources as far away as those in the Ohio River Valley into Minnesota, Wisconsin, Illinois, and Michigan.

Deposition Processes

The subject of pollution deposition can be divided into two categories. One class to dry deposition, which involves impaction of particulate matter on surface material and absorption and adsorption of gases on vegetation, soil and surface water. The other category is wet deposition which incorporates precipitation formation and pollutant removal processes.

The dry deposition flux of any pollutant species can be determined by multiplying the concentration of that species near the ground by the deposition velocity. The deposition velocities have been determined experimentally and have been shown to depend on the rate of diffusion, the characteristics of the underlying surface, the season of the year and atmospheric stability (Eaton, et al. 1979). The deposition velocity of particles is also strongly dependent on particle size.

Although dry deposition monitoring is quite primitive at this time, preliminary measurements indicate that dry deposition of sulfates (usually primary) is more significant than wet deposition near the sources (within several km). This is because wet deposition is a time-consuming process that involves chemical reactions and precipitation. Near the source, many primary sulfate particles either settle out due to turbulent motions that bring a relatively concentrated plume near the ground or through impaction by heavier particulates in the plume. As distance from the source(s) increases, wet deposition becomes more predominant. While no figures on dry vs. wet deposition exist, it is believed that each type of process contributes about equally to the problem.

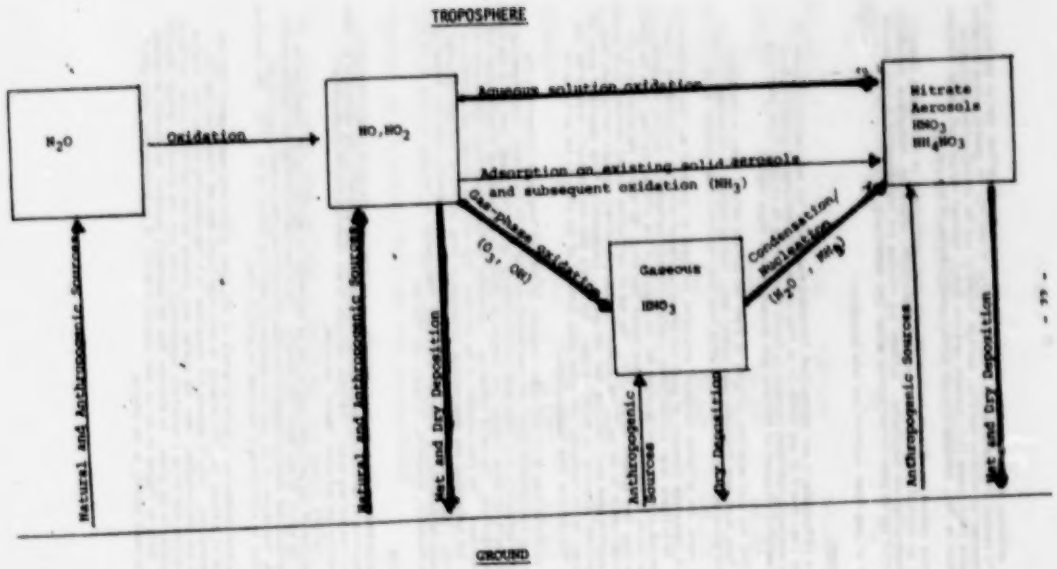

Figure 10. Typical Atmospheric Nitrogen Cycle.

Darker lines indicate primary pathways.

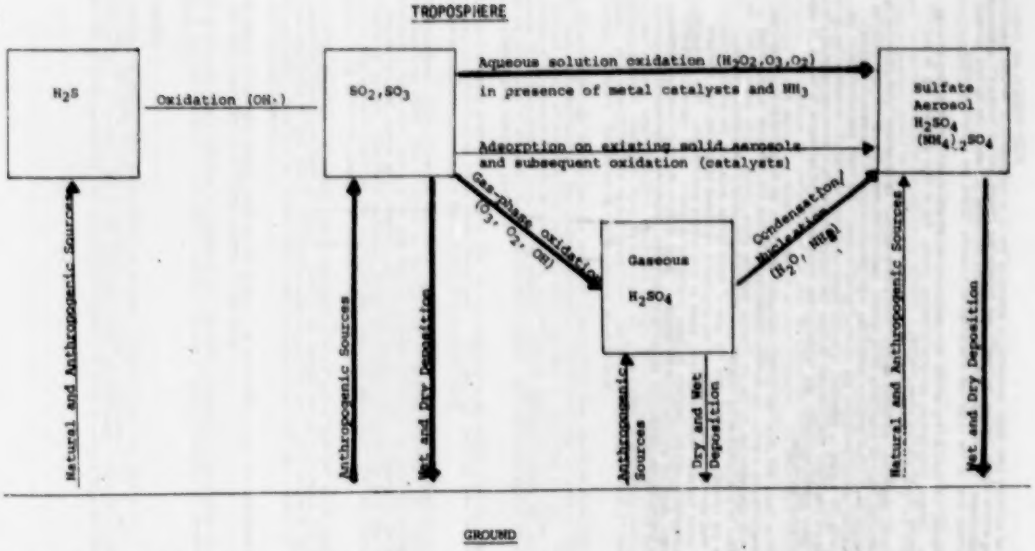

Figure 11. Typical Atmospheric Sulfur Cycle

Darker lines indicate primary pathways.

The concentration of sulfates (and other aerosols) in precipitation is a consequence of several cumulative processes occurring within clouds (called "rainout") and beneath the clouds (called "washout"). Brownian motion, phoretic attachment, inertial impaction, and nucleation all serve to remove the sulfate aerosols from the air and attach them to the cloud and precipitation elements (Scott and Laulainen, 1979).

Once a cloud has formed, the possibility exists for the generation of additional aerosols through other chemical reactions. Indeed, long-lasting non-precipitating clouds, fog or haze droplets may be prolific sources of the aerosols (Scott and Laulainen, 1979).

The removal of soluble, submicron, pollutant aerosol from clouds appears to be accomplished primarily by large collector particles, such as snowflakes or raindrops, sweeping downward through the precipitating cloud and capturing the small cloud droplets containing high concentrations of the aerosol (rainout). Below the cloud, similar removal processes are referred to as washout. The final concentration in the precipitation reaching the ground is dependent upon two features; first, the initial concentration in the collector particles as they start their descent through the region of the cloud where accretion of cloud droplets is the primary growth mechanism, and secondly, the concentration of pollutant in the cloud water accreted by the collector particles.

Recent observations by Scott and Laulainen (1979), and modeling efforts by Scott (1978) have suggested that for certain precipitation events, the sulfate concentration in the precipitation is determined largely by the sulfate concentration in the air flowing into the storm system. Scott suggests that the sulfate concentration in precipitation is highly "episodic", being inversely proportional to the precipitation rate and strongly dependent upon the type of storm system producing the precipitation. Convective storms that develop in the vicinity of the previously mentioned stagnating high pressure systems appear to cause the most severe acid rain, based on preliminary measurements. This is due to relatively large atmospheric aerosol loadings in these precipitation events. Such storms are usually small in areal extent, duration and precipitation amounts. Large scale rain events (stratus, fronts, etc.) have greater precipitation amounts but appear to contain less acidic rain (Barnes, 1979).

3. FUTURE SURVEY AND RESEARCH NEEDS

A. Short-term:

Precipitation Surveys

One of the most pressing needs is to determine the extent and intensity of acid precipitation in Wisconsin.

To expand the current precipitation monitoring network, a minimum of five NADP wet/dry Aero Chem Metrics precipitation samplers should be sited and maintained by the Department according to the NADP specifications in Wisconsin. Wherever possible, dry fall measurements should be taken at all NADP sites. In addition to the existing Trout Lake and Spooner NADP sites, Stevens Point, Devil's Lake, Lancaster and Richland Center are suggested as possible additional locations. Additional sites are being installed by the EPA-Chicago, the Great Lakes National Program office at Duluth, Cornucopia, Ashland, Ontonagon, Copper Harbor, Baraga, Marquette, Escanaba, Green Bay, Two Rivers, and Milwaukee. These sites will be equipped with NADP apparatus, total bulk precipitation monitors, and hi-vol samplers in most cases. Unfortunately, these EPA samples will not be sent to the Illinois Water Survey (the central lab for all NADP sites) for analysis. This reduces the usefulness of the data for comparison purposes but the sites will still give estimates of acid deposition rates in areas in or near Wisconsin. The Department should petition EPA-Chicago, through the Bureau of Air Management, to send all precipitation samples to Illinois Water Survey so that data can be useful for predicting nationwide trends.

All NADP sites in Wisconsin should be funded a minimum of three years and re-evaluated at the end of that period.

Watershed Studies

Since the buffering capacity of any surface water is determined by the characteristics of its watershed, it is important to understand the complex watershed interactions which affect acidification susceptibility. Data on water budgets, water chemistry, subsurface geology, soils, groundwater chemistry and flow, land use, drainage patterns, lake type, size, stream order, etc., are needed to accurately predict susceptibility of surface waters to acidification by acid deposition. Our current knowledge of most of these areas is very limited, therefore, the following studies should be undertaken:

(1) A subsurface geology and hydrogeology survey of a susceptible area should be undertaken. A possible area for study is Forest County. This county represents a transitional zone in terms of glaciation and three distinct levels of susceptibility and has a broad data base on subsurface geology. The scope and duration of this project should be sufficient to quantify the susceptibility of Forest County lakes and streams to acidification. A joint funding proposal should be developed between DNR, USGS, State GS, and the University of Wisconsin to accomplish this project. Well nests and monitoring equipment should be planned this summer if possible.

(2) The Safe Drinking Water Act well data from the non-community water supply sampling program should be monitored for acidification trends every three years. This data set could be used to develop estimates of groundwater buffering capacity in the vicinity of susceptible lakes.

(3) The Department should cooperate with State Geological Survey to analyze the National Uranium Research Expedition (NURE) data collected in 1977 for most of northern Wisconsin. This data was collected in approximately three mile square grids over most of northern Wisconsin and provides information on soils, groundwater, and stream water chemistry which could be very useful in assessing the potential acidification of streams. The State Geological Survey has already worked on the data from the Rice Lake and the Iron Mountain quadrants and has found that localized deposits of fill may account for wide variability in the buffering capacity of surface waters.

(4) The Office of Inland Lake Renewal should encourage a comprehensive hydrogeological study of one or more susceptible lakes in northern Wisconsin. Ideally the susceptible lake(s) should have a pH of less than 6 and alkalinity of less than 5. A complete water budget for the lake(s) should be determined including estimates of surface and ground water input and output rates with measurements of pH and alkalinity for each component.

(5) The Bureau of Research should finalize its proposal to intensively study 3-5 potentially susceptible lakes and their watersheds in different regions of the state.

(6) The Department should continue to cooperate with the USGS in developing appropriate designs for studies of hydrologic budgets of susceptible northern Wisconsin lakes and methods for predicting rates of acidification.

Biota Surveys

The literature is replete with documentation of changes in aquatic flora and fauna owing to lake acidification. The various biological components of the aquatic ecosystem differ in their response to a particular level of acidity. One of the objectives within the Department should be to appraise and document the existing problem of lake acidification within the state in support of a national program.

It is essential to examine the state program on a sound, logical basis and not allow a haphazard approach to "fire-fight" a momentary popular concept. The rapidity of acidification and the existing nature of the problem in the northeastern U.S. and eastern Canada, and the dim prospects for lake recovery make acidification one of our greatest potential freshwater problems at this time.

Upon review of the sensitive areas to acidification within the state, it is readily apparent that the potential problem transgresses Department district boundaries. In conjunction with affected DNR district, a statewide program to monitor and access susceptible lakes should be structured in support of district pursuits. There are several programs within the agency that could be considered for this effort.

(1) The lake classification program using satellite imagery is presently underway. All of the lakes in the State >20 acres have already been computer coded and satellite tapes can be navigated to specific lakes. The program is designed to estimate lake transparency and chlorophyll a concentrations from reflected energy perceived by the satellite. One of the consequences of increasing acidity is oligotrophication of lakes. Long-term chlorophyll a concentrations can be monitored for changes. The disadvantage of the system is that it requires a reasonable level of chlorophyll a to demonstrate a change. However, sensitive lakes that meet the criteria can be determined from the present program.

(2) Expansion of the Office of Inland Lake Renewal (OILR)/DNR District Benchmark Lake Program. Under Chapter 33 of the State Statutes, the OILR program is given a charge to establish a Benchmark Lake Program to monitor long-term changes in selected lakes about the State. A more intensive and specific monitoring program should be established in the districts that have susceptible lakes. This should be coordinated with other research projects.

(3) Whenever possible, OILR should encourage Lake Districts that are created about sensitive lakes to consider a monitoring program that includes the collection of data relating to the acidification problem and assists the DNR district objectives.

(4) The proposed Bureau of Research interbureau-University of Wisconsin study of 4-5 lakes and their watersheds includes biota on land and in the water. This interdisciplinary approach will need assistance from other bureaus and districts plus additional funds.

In an attempt to evaluate changes in the biota as a result of acidification, historical trends in selected susceptible lakes should be studied by paleolimnological methods. Changes in acidophilic plankton (i.e., desmids or diatoms) and sediment chemistry should be examined in deep cores from the selected lakes in conjunction with sedimentation rates to establish observed changes with time.

Perceived changes in the biota are indicators of what has occurred in the aquatic system. A modelling effort should be initiated to predict changes in the aquatic chemistry and biota that may occur in the future, given the present atmospheric loadings and projected trends. Such an effort is paramount for the decision process of the Department in order to allocate the necessary resources to problem areas.

Atmospheric Studies

At present, little is understood concerning the relationship between primary anthropogenic emissions (SO_2, NO_x) and acid deposition, particularly in Wisconsin. Ongoing or recently completed studies on sulfates and long-range transport (e.g. SURE, MAP3S) have resulted in some advances in the knowledge of regional acid precursor transport and transformation.

To establish a more refined precursor-acid deposition analysis program in Wisconsin, the Bureau of Air Management (BAM) recommends that personnel be assigned to the BAM program, both for monitoring and emissions-impact analysis.

The primary goal of the precursor-acid deposition program will be the accurate assessment of regional source culpability (by type and geographic area), to the acid deposition problem in Wisconsin. Once this determination has been made, the most suitable action to limit emissions can be proposed and implemented. In Section 4C of this report, the Bureau has submitted an initial set of proposals to control primary acid precursors (SO_2, NO_x and inhalable particulates). This set of proposals is subject to revision as regulations, control technologies and assessment of the air pollution problems are promulgated.

To analyze the problem in Wisconsin, a more complete regional data base must be established for use with the state-of-the art understandings of the subject. The data base consists of four major components: emissions, meteorology, monitoring, and modeling.

Emissions

Currently, the task force has estimates of state annual SO_x and NO_x emissions totals for numerous point and area source categories for Minnesota, Iowa, Wisconsin, Illinois, Michigan, Indiana and Ohio. These data, collected from U.S. EPA Region V offices, represent various emissions-gathering years (1975 to 1978) and include the current year (1979) data. A need for more up-to-date regional state's SO_x and NO_x emission listing is apparent for uniform assessment of the sources. A letter under the Secretary's signature should be sent to the head of each state's environmental agency, requesting totals of the latest SO_x and NO_x emissions data by category, and a list of major sources (greater than 5 tons per year SO_x or NO_x emissions) by emissions and location (street address, latitude and longitude coordinates). The spatial representation of major SO_x and NO_x point sources will allow for a better visual assessment of their distribution. The data may also be used in any potential acid deposition dispersion modeling program.

Meteorology

To better understand the relationship between SO_2 and NO_x emissions and acid deposition, the long range transport of emissions must be analyzed. Since long-term trends in both acid deposition and wind data are not available, a case study approach to this investigation is proposed. A case study approach is appropriate because of the discrete, episodic nature of wet deposition.

As the wet and dry deposition data bases continue to increase in the state, regional National Weather Service (NWS) and utility-derived meteorological data should be archived for use in case study analyses of days when low pH deposition measurements (less than 5.0) are made. The NWS data (hourly reports, maps, and satellite pictures) can be obtained from the University of Wisconsin Meteorology Department. Utility-derived meteorological data can be obtained from the Bureau of Air Management's Monitoring Section.

An additional source of information on long-range transport of air pollutants (LRTAP) may possibly be the LRTAP study to be done by Mesomet, Inc. Mesomet will be analyzing large scale air pollution episodes from satellite pictures on McIDAS (Man-computer Interactive Data Access System), a University of Wisconsin - Madison computer. This study will be carried out during the summer of 1980 at the UW. The use of satellite data is only a part of a larger contract entitled PEPE (Prolonged Elevated Pollution Episodes), which will be studying particular instances, in a real-time mode, of long-range transport using satellite and other weather information. A meeting between representatives of the DNR and Mesomet should be held to further explore the possibilities of using Mesomet's methods to answer questions regarding LRTAP and its effects in Wisconsin.

Monitoring

Existing methods of monitoring have the following shortcomings:

1. Precipitation samplers and the sampling techniques do not adequately measure the acidity or other constituents of dustfalls and rainfalls. Real-time monitoring is required if accurate and precise data is to be made available for quantitative assessments and modelling purposes. The development of real-time continous monitors for wet and dry deposition is required. Brookhaven National Laboratories has experience with continuous monitors (Tanner, D'Ottavio, Garber and Newman, 1980) for sulfur-containing aerosols. It is recommended that this and other techniques for continuous deposition monitoring be investigated over the coming months for the purpose of contracting to obtain data for comparison to event or "bucket" sampling. Estimated cost: $30,000.

2. Detection limits of ambient monitors are too low to measure gaseous concentrations at ground level. At elevated levels the chances of measurement are improved. It is recommended that aerial monitoring of sulfur and nitrogen oxides and their secondary derivatives (sulfates and nitrates) be contracted. Estimated costs are $50,000 to obtain data along Wisconsin's borders to determine transport into the state, over the acid-sensitive areas and for plume tracking to determine transformation and transport distances.

3. Hi-volume air samplers and other discreet sampling techniques have similar shortcomings for ambient suspended particulate matter as do the precipitation samplers. Continuous monitoring of ambient particulates should be investigated over the coming months and equipment purchased to provide data on ground level concentrations of respirable ("fine") particulates and their sulfate/nitrate content. Estimated costs vary between $5,000 per instrument and $30,000 per instrument. Location of such monitors at the five deposition sites will lead to total costs between $25,000 and $100,000.

4. Elsewhere in this document there is a proposed requirement for continuous in-stack monitoring of emissions from point sources. This will require a very large quality assurance program which will require personnel and auditing equipment. Estimated annual costs are $50,000.

5. To support the efforts listed above will require 1.5 person/year.

Total Monitoring: $155,000 to $280,000 plus 1.5 position.

Assuming that adequate monitoring, emissions and meteorological data bases can be established for the acid deposition study, a dispersion modeling program should be seriously considered for attempting to better estimate both the relative impact of airborne acid precursors and acids, and ascertaining likely areas of emission culpability on an event-by-event basis.

The state-of-the-art in dispersion models that incorporate long-range transport, chemical transformation and deposition processes is continually improving. A survey of existing long-range transport/deposition models should be studied for their potential use in a long term study.

Two case studies using a modeling approach have been proposed:

1. A study to estimate, by diffusion modelling, the probable impact on acid deposition of major existing Wisconsin sources of SO_2 and NO_x on the acid-sensitive areas of northern Wisconsin.

Estimated Cost: $75,000

2. A study to estimate the probable increase in precipitation pH as a result of emission reductions from these sources?

Estimated Cost: $25,000

Total Modeling: $100,000

B. Long Term

Long-term studies of acid deposition effects are needed in several research areas. Effects of acid deposition have been predicted or measured in Scandanavia in the following systems:

Agriculture	Forestry	Soils	Lake Ecosystems
Groundwater	Fisheries	Materials	

If Wisconsin is to accurately measure potential effects of acid deposition, which may take years to manifest themselves, it will be necessary to carry out long-term research in each of the above areas of study.

The Task Force believes first priority should be given to assessing the probability of short-term impacts in Wisconsin. If funds are available, long-term research should be carried out as long as the main focus of the Department's actions continues to center on control of acid depositon from local sources or long-range transport of pollutants.

C. Ongoing Agency Activities and Capabilities to Perform Research:

State Agency Activities

Because of its general responsibilities for air and water quality, the Department of Natural Resources should be and is the lead agency pertaining to acid rain research. The Department has been monitoring lakes for a number of years and precipitation since the summer of 1979. This monitoring will continue through the summer of 1980 at which time funds for this work will be exhausted. The Department is involved in two other summer 1980 lake studies including the assessment of fish populations in selected lakes. These two studies are being done jointly with the U.S. Fish and Wildlife Service and EPA's Duluth Laboratory.

The Public Service Commission is not doing acid rain research, but is involved in the Advance Plan Hearing process for future power plant sitings. The Commission is very interested in the impact of acid rain on northern Wisconsin and will consider this issue when making future decisions on power plant sitings. The Commission can call for research on the part of power companies as part of their siting orders.

The Department of Transportation has expressed concern about the effect of acid rain and low pH surface waters on road surfaces and culverts. Metal culverts are apparently being eroded faster than normal in the northern part of the state. An attempt to identify causes for faster degradation in this area is being made.

Because of this report the Wisconsin Legislative Council will not conduct a study of acid rain as previously planned. The Council staff will, however, develop a brief information paper for legislators prior to anticipated Assembly Environmental Resources Committee hearings on the subject later this summer.

The University of Wisconsin Extension, Environmental Resources unit, has been very active in the acid rain issue. The extension has issued an informational press release on acid rain and has held a symposium on the subject. Regional workshops will be held in several locations in northern Wisconsin this summer. Continued emphasis on developing educational programs on acid rain is anticipated by the Extension.

The State Geological and Natural History Survey has done considerable mapping of the bedrock geology and glacial geology in northern Wisconsin. The Survey has also conducted an extensive soil, ground and surface water monitoring program under the National Uranium Research Expedition (NURE). Data was collected in 3½ mile grids over most of northern Wisconsin. The pH and alkalinity data that are available could be very useful in assessing potential acidification of streams and groundwater. However, the Survey does not have funds to analyze the data.

The Economic Statistics and Cooperative Service (Dept. of Agr. Econ. - U. Wis.) has submitted a proposal to EPA and the National Science Foundation which outlines a project that would estimate the economic impact of acid rain on Wisconsin recreation.

Information on the status, progress and findings of these various state agency activities should periodically be made available to the Acid Deposition Advisory Subcommittee of the statewide Water Quality Advisory Committee so that all agencies may be kept informed about acid rain research.

Federal

Various federal agencies are studying acid deposition on their own and with cooperation from state agencies, universities and other organizations. Following is a list of federal research projects and monitoring networks already completed or currently underway on acid deposition:

Environmental Protection Agency

(1) Multistate Atmospheric Power Production Pollution Study (MAP3S)

Begun in 1975, this study's goal is to understand where acid rain comes from and how it forms. Researchers are examining pollutant concentrations, atmospheric behavior, and precipitation chemistry as related to large-scale power production, especially coal combustion. Researchers are also operating eight precipitation chemistry stations throughout the northeastern U.S. MAP3S researchers cooperate with acid rain studies conducted by the Electric Power Research Institute.

(2) Midwest Interstate Sulfur Transformation and Transport (MISTT) project

A recently completed study which investigated transformation of sulfur dioxide/sulfates and long-range transport of air pollutants.

(3) Sulfur Transport and Transformation in the Environment (STATE)

The goal of this study, begun in 1978, is to quantify the impact of various regional air pollution sources on air quality. The major field effort for the summer of 1980 is concentrated in the Ohio River Valley.

(4) Argonne Labs Great Lakes study

Through interagency agreements Argonne is studying the effects of wet and dry deposition of atmospheric pollutants in the Great Lakes region.

(5) Environmental Research Laboratory -- Corvallis, Oregon

This EPA laboratory is investigating crop reactions to acid deposition and possible effects of western coal conversion on terrestrial ecosystems.

(6) Environmental Research Laboratory -- Duluth, Minnesota

Researchers are looking at the susceptibility of aquatic and terrestrial resources in Minnesota and Wisconsin to damage from atmospheric pollutant deposition and loading.

(7) Office of Environmental Processes and Effects Research -- Washington, D.C.

This EPA office aids the U.S. Department of Energy's efforts in acid rain studies conducted at national laboratories at Brookhaven, Oak Ridge and Argonne. The office also supports precipitation monitoring coordinated by the U.S. Department of Agriculture, and participates in experimental watershed projects with the Tennessee Valley Authority.

(8) Environmental Monitoring and Systems Laboratory -- Research Triangle Park, North Carolina

This lab develops quality assurance techniques for collecting, standardizing and analyzing atmospheric and aquatic acidity, and methodology for standardizing sampling and air monitoring.

(9) Office of the Assistant Administrator -- Washington, D.C.

This office is responsible for developing a 5-year plan for EPA's Atmospheric Acid Deposition Program, and determining effects of individual pollutants on materials such as stones and metals.

(10) PEPE - Prolonged Elevated Pollutant Event. A study undertaken by EPA, Research Triangle Park, NASA and Mesomet, Inc., which is intended to gather information on transport and deposition of acid rain precursors.

Monitoring Networks

(1) National Atmospheric Deposition Project (NADP)

This interagency research effort is studying chemical changes in atmospheric deposition and the effects of acid rain on agricultural and forest land and surface waters in the U.S.

Its objectives are to:

- determine spatial and temporal trends in deposition,
- determine the relative importance and contributions of precipitation, dry particulate matter, aerosols and gases to total atmospheric deposition,
- develop optimum procedures for collecting precipitation and dry deposition,
- determine the stability of certain constituents of precipitation,
- investigate transport and transformation of atmospheric constituents,
- organize and coordinate research on effects of changes in atmospheric deposition: (1) productivity of forests, rangelands, wetlands, agricultural crops and surface waters; (2) health and productivity of domestic food animals, wildlife and fish; and (3) corrosion of metals, painted surfaces, masonry and other materials in machinery and structures.

The NADP network now has over forty monitoring sites across the U.S. (two in Wisconsin). A total of eighty is projected. Wet deposition is collected weekly, and dry deposition bimonthly. Samples are analyzed by the Illinois State Water Survey, with quality control supervised by the U.S. Geological Survey. Other agencies involved in the study include state agricultural experiment stations, the U.S. Forest Service, Agriculture Research Service, U.S.G.S., National Aeronautics and Space Administration, EPRI and EPA (MAP3S), National Park Service, Federal Bureau of Land Management and others. The Wisconsin DNR is currently the only state resource management/pollution control agency operating a NADP station.

(2) EPA/National Oceanic and Atmospheric Administration/World Meteorological Organization -- EPA/NOAA/WMO

This is a global monitoring network established by WMO to determine long-term global acid precipitation trends. EPA is coordinating the U.S.'s contribution to WMO's 15 station network. Precipitation samples are collected monthly and sent to EPA for analysis. Data are published annually from NOAA's National Climatic Center in Ashville, North Carolina.

(3) U.S. Department of Interior -- Office of Water Research and Technology

Program researchers study acidified lakes and the effects of acid deposition on aquatic life. The study is contracted to affiliates in New York, Pennsylvania and New England states. Maine lakes are being studied for their heavy metal content, sediment chemistry and fossils of microscopic organisms, in the hope of reconstructing the history of acid rain's impact on area lakes. In New York the effects of acid deposition on phytoplankton are being studied; in Pennsylvania, acid snow in mountain streams. The program is also testing reversal of acid rain's harmful effects, such as raising pH using neutralizing materials such as lime, limestone, calcium carbonate and fly ash.

Other Involvement

(1) Canada and the United States have pledged to accelerate a timetable for achieving bilateral agreement on transboundary air pollution. Formal political negotiations are not expected for some time, however.

(2) In late November, 1979, at the International Convention on Transboundary Air Pollution in Geneva, over 30 countries pledged to limit, reduce, and prevent all forms of air pollution. Acid deposition was singled out for special attention. This pledge is unprecidented, but weak. It calls for cooperative research, establishment of a monitoring network and an information exchange, but not for control strategies.

(3) Federal Acid Rain Assessment Program

President Carter established a ten year comprehensive program involving applied and basic research on acid rain's environmental effects, trends in air pollution monitoring, transport and fate of air pollutant and control measures. The program will establish links with industry to promote cooperative research. In its first full year of operation, the program will have $10 million in reprogrammed research funds available, double the current amount available for acid rain research. The program will be planned and managed by a standing Acid Rain Coordination Committee. (Recently the "Acid Precipitation Act of 1979" was passed making additional funds available. This act is discussed in sections 4.8. and 4.D.).

EPRI (Electric Power Research Institute) Research Activities

The Electric Power Research Institute (EPRI), a research organization established and funded by the utility industry, is conducting a number of scientific studies concerned with acid rain. The Institute is undertaking a comprehensive approach to acid deposition by funding studies which deal with most of the major phases of the acid deposition process, from the emission of precursors to the actual deposition of acid on the ground and subsequent environmental effects. The EPRI-funded Sulfate Regional Experiment

(SURE) is designed to help determine the contribution of fossil fuel power plants to atmospheric sulfate concentrations in the northeastern United States (National Commission on Air Quality, 1979). Another study involves the collection of atmospheric water from a stack plume being tracked from a power plant in England across the North sea to the point where precipitation falls from the plume over Norway. The study will attempt to determine the mechanism by which atmospheric acid is created and to calculate the United Kingdom's contribution to acid deposition in Norway (Air/Water Pollution Report, 1979; EPRI, 1979).

In an EPRI funded program conducted by Rockwell International in the Northeastern United States, researchers are monitoring precipitation chemistry at nine SURE stations and are then using weather data in efforts to identify the sources of the acid deposition measured at these sites (EPRI, 1979). An ambitious study in the Adirondacks rounds out EPRI's research picture by dealing with the bottom line aspect of acid deposition, its environmental effects. This investigation focuses on the waters and watersheds of three lakes, one of neutral, one of variable, and one of high acidity. A total-system approach is used in that as many of the physical chemical, and biological processes as possible in each watershed are monitored in an attempt to determine the impacts of acid deposition on these processes. Lake sediment cores will also be taken in order to establish historical trends in lake acidity if possible (EPRI, 1979).

Further EPRI sponsored studies currently underway which supplement those just described include an examination of the extent of acid deposition in the Adirondacks, a western regional air quality study (looks into long-range transport and the aerial extent of acid deposition), and projects dealing with sulfate formation in power plant plumes, dry deposition of sulfur dioxide and sulfate aerosols, aerosols and cloud droplets transformations of sulfur oxides, the effects of sulfur dioxide on crops and grasslands, and the interactions of acid deposition with a forest microcosm. Future projects will look into additional aspects of the effects of acidity on forest and aquatic fauna, and the effects of sulfur dioxide on crops.

University of Wisconsin

A number of research programs have either begun or have recently been proposed at several campuses in the University of Wisconsin system. The majority of the research related to acid rain is taking place at the Madison campus. Three independent investigations in Wisconsin have confirmed the existence of acid rain in Wisconsin.

Apparently, the earliest documentation of acid rain in Wisconsin was made by researchers at UW-Milwaukee Field Station (Kobriger 1975) as part of a study on mineral cycling in a hardwood forest. The pH of precipitation in the Northern Highland State Forest was measured by Pastor (1980) from 1978 through 1979 as part of a study on nutrient recycling in forests. In addition to this precipitation data, the pH of rainfall at Trout Lake, Vilas County, was measured in conjunction with a study on heavy metal movement from the atmosphere to the lakes (Talbot 1979).

The chemistry of precipitation in central Wisconsin is now being measured by investigation at UW-Stevens Point (Shaw 1980).

A study of the relationship of glacial geology to lake water chemistry (and, therefore, susceptibility to acid rain) was initiated by researchers at UW-Madison (Simpkins and Mickelson 1980). A proposal to EPA-Duluth to continue this research by Mickelson and Kenoyer was not funded for 1980.

The Limnology Laboratory (UW-Madison) has undertaken a brief review of historic lake data for northern Wisconsin lakes. Completion of this project is dependent upon the ability to make additional observations of the lakes and make the appropriate comparisons with the data collected in 1925-1941.

An interdisciplinary team of researchers representing limnology, water chemistry, hydrogeology, and microbiology from UW-Madison has submitted a proposal to NSF for a five-year study of selected northern Wisconsin lakes (Magnuson 1980). One aspect of this study would include examining the impacts (or potential impacts) of acid rain on lake ecosystems. The indepth studies proposed will provide information on potential or actual acid deposition impacts for at least three lakes but probably will not be very useful in assessing the extent and distribution of susceptible lakes in northern Wisconsin. Several departments within the University plan to participate in this proposed project.

Although there are a number of researchers in the University of Wisconsin system with expertise and interest in examining specific questions relating to acid rain in Wisconsin, as of this writing, major research efforts designed to provide answers to the many questions regarding acid rain are not being funded.

D. DNR Needs for Additional Research:

General

The Department has several general needs for additional research. Given our state's present position of having susceptible lakes and soils, and receiving acid precipitation (pH 4.5), it may be only a matter of time before damage results. The first question we need to answer is whether acidification has already occurred, and if not, how long will it be before acidification occurs if conditions remain unchanged.

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Another important need for additional research pertains to the Department's responsibility of assessing the environmental impacts of major energy projects in Wisconsin. The Wisconsin Environmental Policy Act (WEPA) directs the Department to assess such impacts, yet very often the information required to determine environmental impacts is lacking. In the case of acid deposition, our agency has a legitimate reason to require and/or perform research needed to provide this vital information.

Because of the magnitude of the research required, the Task Force proposes that Wisconsin utilities join in the investigation of environmental effects of acid deposition. While determinations of the contributions of particular power plants to the acid deposition problem are not feasible at this time, the Task Force believes that local utilities are contributing to the problem, and should also contribute to the search for solutions. We are convinced that with guidance from the Department, a Wisconsin utility-sponsored acid deposition research program would be very useful to both organizations.

Voluntary studies undertaken by the utilities would be the preferred course of action, but several mechanisms are available to ensure utility cooperation:

(1) Require acid rain research as part of the air emission permits.

(2) Request acid rain research as part of the Public Service Commission advance plan orders.

(3) Require acid rain research as part of the environmental report submitted by a utility.

District Needs

Northwest District Water Quality staff should begin using susceptibility prediction techniques developed by North Central District to assess the potential for acid deposition problems in that part of the State. Northwest District Air Management staff should maintain an NADP site at Spooner. These efforts will require a 1/2 FTE/year for three years.

North Central District staff should continue to maintain the NADP site at Trout Lake and the event related deposition monitoring at several sites. North Central District should continue to conduct the acid deposition assessment which it started in April, 1979. Literature review, and the monitoring of precipitation, lakes, fish, and potentially affected ecosystems should be continued. Contacts with cooperating agencies and researchers should be maintained. The District staff should assist other districts in assessing the susceptibility of aquatic ecosystems. North Central District will require the following itemized budget to continue acid rain work:

2 FTE's @ $19,000 each	$38,000
22% fringe 4,180	8,360
	46,360
Services	6,000
Supplies	4,000
Equipment	1,000
	57,360
Trout Lake NADP Site	3,400
Total cost	$60,760 per year for 3 years

Bureau Needs

The Bureau of Water Quality requires a 1/2 FTE/year to chair the Acid Deposition Task Force, coordinate acid rain activities with other state and federal agencies, and serve on the Department's Research Steering Committee to review funding applications/proposals for acid rain research.

The Bureau of Air Management has estimated their needs at 1.5 FTE/year and approximately $300,000 to perform the monitoring and modelling described in section 3.A.

The Bureau of Research has prepared a preliminary research proposal which would involve several other bureaus including Forestry, Fish Management and the University of Wisconsin Soils Department. Their estimated funding need is approximately $60,000/year for 3 years.

4. RECOMMENDED ACTION

A. DNR Work Plan Adjustments:

The Benchmark Lakes project should be modified to include at least five lakes susceptible to acidification by acid deposition in the North Central District and Northwest District. Lakes should be selected for maximum sensitivity and should be used as indicators of potential damage.

Other selected lakes should be sampled throughout the year during spring breakup, spring turnover, summer, fall turnover, and winter. Additional snow cores should be collected to determine total acid loading to the watershed and runoff quality and quantity. This program should be coordinated with the lake-watershed studies proposed in the Bureau of Research interbureau - University of Wisconsin project.

DNR Northwest District should allocate sufficient time to operate the Spooner NADP site and to use available data to assess the susceptibility of NWD lakes to acidification using the criteria and assessment system developed in the North Central District.

B. Legislative Action to Appropriate Research Funds:

State

Wisconsin presently has no money budgeted for acid rain research. All previous work on acid rain has been funded by non-renewable federal "208" dollars, which terminates in July, 1980. Therefore, a serious need exists for appropriations to fund a concerted and long term program for both research and implementation of measures to control acid rain in our state.

The Minnesota Legislature recently passed a bill which appropriates an initial $100,000 for starting an acid rain research program. Additional annual appropriations are anticipated by the Minnesota Pollution Control Agency.

This Task Force recommends that the Department of Natural Resources request $445,000 in the next biennial budget for surveys and research to be conducted by the North Central and Northwest Districts, and the Bureaus of Air Management, Water Quality and Research.

Federal

The United States Congress recently passed a very important bill regarding acid rain research funds. The "Acid Precipitation Act of 1979", Title X of Senate Bill 932, authorizes $55 million over ten years to support acid rain activities. Title X directs a federal Acid Deposition Task Force to cooperate with states in studying the acid deposition problem. However, no funding has been specifically allocated for state activities. It is recommended that DNR contact the federal agencies (NOAA, Dept. of Agr., EPA) administering the funds and make our long-term financial needs known as soon as possible.

C. Action to Control Emissions:

The acid deposition phenomenon must be viewed in the more general context of air pollution. The deposition of acids and acidifying substances is a symptom or effect of polluted air and can be considered a consequence of the secondary formation of sulfates, nitrates and ammonium from precursor gases such as sulfur dioxide and nitrogen oxides.

In that context, the Bureau of Air Management should be mandated to work with state and federal legislatures, other state air regulatory agencies and the U.S. Environmental Protection Agency to carry forward strategies and programs designed to reduce acid deposition. This can be accomplished by controlling and monitoring the emissions of acid-precursors. The Department as a whole should be mobilized to support such efforts through action by the Natural Resources Board and the authority of the Secretary. The Department, through the Bureau of Air Management, should pursue the following policies on acid deposition endorsed by the Natural Resources Board on April 24, 1980:

"(1) The Department should seek administrative and regulatory action under Section 111(d) of the Clean Air Act. (Section 111(d) authorizes the establishment of standards of performance for any existing source for any air pollutant and procedures for implementation and enforcement of such standards of performance.)

(2) A nationwide requirement for coal washing in order to remove substantial quantities of pyritic compounds.

(3) Legislative action to amend the Clean Air Act to require nationwide emission limits.

(4) Retrofitting of existing power plants to meet nationwide emission limits.

(5) Nationwide emission monitoring.

(6) Nationwide consistency among EPA regions in requirements and enforcement."

The actions recommended by the Natural Resources Board address some of the shortcomings of the Federal Clean Air Act. These and other potential actions are presently under consideration by the State and Territorial Air Pollution Program Administrators (STAPPA). The following is adapted in part from STAPPA preliminary documents and clarifies the preceding policies:

1. Section 111(d) of the Clean Air Act

Section 111(d) of the Clean Air Act focuses exclusively on emissions from existing air pollution sources, including existing fossil fuel-fired power plants. Section 111(d) directs EPA to issue regulations which, in turn, require the state to establish "standards of performance" to control pollutants such as acid rain. Each "standard of performance" must require the emitter to install the Best Available Control Technology (BACT), taking into account the remaining useful life of the facility.

New Source Performance Standards (NSPS) are currently required for sulfur dioxide and/or nitrogen oxides from new or modified sources. Sulfur dioxide and nitrogen oxides convert to sulfates and nitrates in ambient air; therefore, it can be implied that NSPS for sulfates and nitrates exist.

Section 111(d) requires EPA to adopt emission limits for existing sources of "non-criteria" pollutants when NSPS are adopted for the same pollutant-source. Sulfates and nitrates are "non-criteria" pollutants.

2. Coal Washing

To reduce the total sulfate burden as soon as possible, a national program requiring coal washing should be mandated. Coal washing represents a first step that could be taken to reduce sulfur emissions. According to current thinking, a coal washing program, using the best available technology, could achieve sulfur reductions of between 10 and 30 percent. Coal washing on a national level is a cost-effective means to reduce emission levels.

Certainly, there are clean coals available, and such a requirement should not be imposed on low sulfur coal. However, much of the coal available in the East, the area most affected by acid precipitation, is not low in sulfur, and coal washing could help achieve both a cleaner and more efficient fuel source.

Some states already are taking steps to require coal washing; however, to achieve national objectives and continue efforts to protect the environment, it is important that the requirement that utilities burn cleaned or clean coal be made on a national level.

3. National Emission Limits

The states and EPA should join together in a request to Congress to amend the Clean Air Act so as to require emission limitations on existing sources. Emission limitations for the larger emitters of transported pollutants should be developed as a first priority. EPA should be given the responsibility for development of existing source emission standards, but the states, industry and the affected public must have a role in the standard setting process.

By making such a change to the Clean Air Act, Congress would be recognizing equity of control measures and the inequity caused by the current State Implementation Plan (SIP) process.

EPA may request legislative authority under the Clean Air Act to enforce a regional cutting on mid-western industrial and utility emissions that contribute to acid rain. Three specific strategies are under consideration: 1. a "maximum emissions cap" in lbs/mmBtu for sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions for each source; 2. a "regional emissions budget" approach in tons per year; 3. an emissions fee, with the fee based on the avoided cost of installing increased pollution control. EPA should continue to pursue this action as a necessary step to establishing National Emission Limits.

Wisconsin regulations to control emissions from existing sources appear in Wisconsin Statute 144 and Wisconsin Administrative Code NR 154. A new state permit law restricts ("lock in") existing source emissions to pre-determined levels. This law will be implemented in 1983.

4. Power Plant Retrofit

Consideration should be given by Congress to require all existing power plants to be retrofitted to be consistent with national emission limits within a reasonable number of years so as to achieve an emissions reduction of pollutants on a nationwide basis.

5. Emissions Monitoring Program

As the nation becomes more and more dependent upon coal as a fuel, it is important that good information be developed on the amount of sulfur dioxide and nitrogen oxides actually emitted from power plants. Therefore, each coal-fired power plant should be required to install continuous in-stack monitors to provide the operators with up-to-the-minute information on plant emissions.

Such a system allows utilities to exercise much more effective control on their day-to-day plant operations. Monitoring systems utilizing high speed computer technology are now available and can easily provide the information necessary to completely monitor emissions.

4. National Consistency

Current emission standards for existing fossil fuel-fired power plants vary widely from state to state; most permit far greater emissions of sulfur and nitrogen oxides than warranted, lagging years behind developments in pollution control technology. Section 111(d) allows EPA to redress this situation, making all facilities subject to the best controls possible. It thus offers the potential for significant reductions to acid rain.

To assure consistency of actions among EPA regions, STAPPA proposes that the Administrator should establish a National Consistency Review Council (NCRC) which will act as an appeals board and report its recommendations to the Administrator.

The NCRC would be made up of one member from each EPA regional area with the members representing EPA Regional Administrators, State Air Pollution Administrators, elected officials, industry and commerce, and the environmental public. This committee of ten would review requests where there is a feeling that inequitable and inconsistent treatment has taken place.

Other Actions

A number of other policy and technological actions exist or are presently being developed. These include the conservation of energy through public education, legislation, economic incentives and advanced technology; the development of alternative energy sources, such as wind, solar and biomass, including provisions for tax relief and other financial incentive, replacement or growth of electric generating facilities to less acid-committing areas through dispersed (small) vs. single, large sources; allocating and prioritizing fuels from least polluting (natural gas, alcohol) to most polluting (coal, oil); dispatching power based on a least emissions priority, with more environmentally efficient plants used first, rather than priority based on the more traditional least-cost dispatching; using regulation to promote shorter plant life cycles to encourage more rapid turnover of less environmentally efficient plants (retrofit and depreciation after "average" retirement age of plants); technological improvements in emissions control; and actions, other than Section 111(d), under the Clean Air Act.

Existing technology and technology in the development stage include staged combustion, fluidized bed combustion, electrostatic precipitators, Flue Gas Desulfurization (scrubbers) and the injection of limestone or ammonia into flue gas exit stacks. Reviews of nitrogen and sulfur oxides control technology can be found in "Sulfur Oxides: Control Technology and Waste Management", EPA-600/8-78-019, and "Research Summary: Controlling Nitrogen Oxides", EPA-600/8-80-030.

Emissions limitations potentially affecting acid precursors that are currently in effect include: 1. existing emissions limitation for new sources in individual state implementation plans; 2. minimal increments of pollution allowable under Prevention of Significant Deterioration (PSD) regulations; 3. individual states' permit load for emissions from existing sources; and 4. Reasonably Available Control Technology (RACT) and emissions offset requirements to mitigate air pollution problems in nonattainment areas of the National Ambient Air Quality Standards (NAAQS).

Reasonably Available Control Technology (RACT) is to be applied to those existing sources that have been judged to be impacting significantly on those (nonattainment) areas where National Ambient Air Quality Standards have been violated. In addition to RACT, a "no emissions growth" policy will be mandated for most nonattainment areas. The net emissions for the NAAQS criteria pollutants in question will not be allowed to increase, meaning that emissions from a new source must be offset by an emission reduction elsewhere in the area.

All of these emission-reduction regulations have their origin in the Federal Clean Air Act. However, acid deposition may not be adequately controlled by the Clean Air Act in its existing form because sulfates and nitrates are not considered priority pollutants. In addition, relief which should be available under the Clean Air Act is not currently being implemented. Many serious acid deposition cases among states that burn or produce large amounts of coal and states that receive the pollution from coal-consuming states. EPA's existing tall stacks policy and the failure to effectively use the Prevention of Significant Deterioration clause in the Act, both aggravate the acid deposition problem. For an in-depth discussion of the weakness of the Clean Air Act as it applies to acid deposition, see reference titled "Air Pollution Control Laws in North America and the Problem of Acid Rain and Snow" (Bekedam, 1980).

Although the Clean Air Act was not designed for control of acid rain, there are several steps that could be taken by EPA and the states within the existing provisions of the Act. Several of these measures could be adopted in a relatively short time (compared to revision of the Clean Air Act or development of alternative legislation).

The following measures, adapted in part from the Natural Resources Defense Council policy, could be taken by EPA to reduce existing and future emissions which cause acid rain.

1. Adopt Adequate Regulations To Control the Use of Tall Stacks

Section 123 of the Clean Air Act directs EPA to promulgate regulations limiting the extent to which tall stacks can be substituted for emission controls. Presently, stack height is designated by "Good Engineering Practice" (GEP), normally two and a half times the height of nearby structures. These regulations are necessary because the taller the stack assumed in a model, the less emission control will be needed to have the model predict low concentrations of a pollutant in the ambient air at ground level.

The absence of stack height regulations has a twofold impact on acid rain: 1. it increases the amount of emissions that can be discharged to the atmosphere in apparent compliance with ambient air quality standards, and 2. it encourages sources to inject these emissions into the air at ever greater heights, thereby increasing the time that pollutants remain suspended in the air and the distance they travel.

EPA SHOULD PROMULGATE EFFECTIVE REGULATIONS REQUIRING EMISSION CONTROLS FOR ACHIEVING AMBIENT STANDARDS AND PROHIBITING CREDIT FOR STACKS GREATER THAN THE GEP HEIGHT.

2. Adopt and Implement Proper Noncompliance Penalty Regulations Immediately

Section 120 of the Clean Air Act compels EPA to issue regulations requiring noncompliance penalties from any major air polluter violating emission standards after July 1, 1979. Although applicable to all industries, the noncompliance penalties are particularly essential to the control of acid rain for utilities, the largest industrial sources of acid rain-causing pollutants.

Congress ordered EPA to promulgate such regulations by February, 1978 and to implement them by July, 1979. To date they have not been adopted. EPA SHOULD PROMULGATE THE REGULATIONS AND FOLLOW UP BY ISSUING NOTICES OF VIOLATION PROMPTLY. UTILITIES AND OTHER MAJOR VIOLATORS OF SULFUR AND NITROGEN OXIDE EMISSION LIMITS SHOULD PAY PENALTIES EQUAL TO THE ECONOMIC ADVANTAGE REAPED BY THEIR FAILURE TO INSTALL POLLUTION CONTROL EQUIPMENT. IN ADDITION, VIOLATORS SHOULD BE FINED FOR PUNITIVE DAMAGES. This program would thus constitute a powerful incentive to induce compliance with the current law.

3. Adopt Effective National Ambient Air Quality Standards for "Fine" Particles

Congress directed EPA to set national ambient air quality standards for these pollutants under s. 108 and s. 109 of the Clean Air Act because ambient standards set a number of critical control programs into motion: state plans to reduce emissions of fine particles and the gases which form them; a national air quality monitoring network to detect dangerous levels of pollution before irreversible environmental damage occurs; and increased focus on long-range trans- of fine particles across state boundaries.

The Total Suspended Particulates (TSP) ambient air quality standard is currently under review by EPA (See "Air Quality Criteria for Particulate Matter and Sulfur Oxides", external Draft Review No. 1, April 1980). TSP can be categorized as respirable particles (less than 2.5 um), those particles that penetrate to the alveoli of the lungs, and inhalable particles (less than 15 um). Respirable particles, in particular, endanger public health because they may contain toxic material and penetrate deeply into the lower lung where they cause greater respiratory damage than other pollutants regulated by EPA. These fine particles, consisting largely of sulfates and nitrates, are also principal culprits in the acid rain problem and visibility reduction.

Action by EPA to establish a respirable particulate NAAQS is not expected at this time. Reliable and accurate methods for measuring such particles are not available. EPA SHOULD BE ENCOURAGED TO CONTINUE INVESTIGATIONS INTO THE METHODOLOGY FOR MONITORING RESPIRABLE PARTICULATES.

An inhalable particulate ambient air standard is expected to be proposed by EPA in December, 1980. This should provide a better measure of protection for public health than the present TSP standard and should provide some measure of relief for such welfare effects as acid deposition. EPA SHOULD PROMULGATE THIS STANDARD NO LATER THAN ITS PROPOSED DATE.

4. Adopt Effective Regulations to Safeguard Visibility

The Clean Air Act gives EPA authority to prevent acid rain in vulnerable parks and wilderness areas categorized as Class I. Section 169A of the Clean Air Act directs EPA to promulgate regulations to prevent future and remedy existing impairment of visibility in these priority areas.

Visibility regulations were proposed on May 15, 1980. This proposal includes employing BACT (Best Available Control Technology) on sources contributing to visibility impairment in Class I areas. Since the pollutants which impair visibility -- those particles, particularly sulfates, less than 1 micron in size -- are the same pollutants responsible for acid rainfall, the promulgation of regulations to promote the national goal of visibility protection would also reduce acid rain.

EPA SHOULD ASSURE THAT THE FINAL REGULATIONS TO BE PROMULGATED (PHASE II) BE EFFECTIVE IN DEALING WITH URBAN PLUMES AND REGIONAL HAZE. These would, in addition, contribute to controls of the acid deposition problem.

A thorough review of the parameters affecting visibility, visibility reduction and visibility monitoring can be found in "Protecting Visibility: An EPA Report to Congress", October, 1979.

5. Revise Air Quality Modelling Assumptions to Insure Attainment of National Ambient Air Quality Standards

EPA continues to approve state plans based upon questionable modelling data that do not assure the reduction of criteria pollutants which contribute to acid deposition. Section 110(a)(2)(B) of the Clean Air Act requires each state plan to "insure" attainment and maintenance of those ambient air quality standards throughout the state. Likewise, Section 163 of the Act requires each state plan to "contain measures assuring" that prevention of significant deterioration increments will not be exceeded. Air quality modelling has been the primary tool used by states and industrial interests to accomplish these objectives. The assumptions used in applying the results of models fail to provide the assurance the law requires that excess emissions will not be allowed. EARLY IN 1980, EPA PLEDGED THAT THE AGENCY WOULD CONDUCT A COMPREHENSIVE REEXAMINATION OF THE ASSUMPTIONS THAT PERTAIN TO THE USE OF MODELLING. THIS ACTION SHOULD BE IMPLEMENTED BY EPA WITHOUT FURTHER DELAY.

6. Investigate Using the Residual Authorities of the Clean Air Act

Courts have taken a broad view of the general purposes provision of the Clean Air Act, Section 101(b), construing this section as a mandate to EPA to prevent deterioration of air quality even in the absence of expressed statutory language. Thus even if more specific provisions of the Clean Air Act did not give EPA sufficient power to prevent acid rain, EPA would still, under S. 101(b), have authority to adopt comprehensive programs to curtail acid rain-causing pollutants.

Its doubtful that EPA need look to the general mandate of S101(b) in view of the many directives throughout the statute to take steps to control the pollutants responsible for acid rain. BUT EPA SHOULD USE THIS GENERAL AUTHORITY IF NECESSARY TO SUPPLEMENT THE MEASURES WE HAVE OUTLINED SO THAT THE ACID RAIN PROBLEM CAN BE FULLY RESOLVED.

7. Include Protection Against Acid Rainfall in Any Coal Conversion Legislation

The Administration's proposed coal conversion bill would allow at least 400,000 to 600,000 additional tons of sulfur and nitrogen oxides to be emitted each year into the atmosphere of the northeastern U.S. If enacted into law, this bill would worsen acid rain here and in Canada and postpone any progress further into the future.

THE STATE OF WISCONSIN THROUGH THE GOVERNOR, THE LEGISLATURE AND THE DEPARTMENT, SHOULD CALL ON THE CARTER ADMINISTRATION TO IMPROVE ENVIRONMENTAL SAFEGUARDS PROVIDED IN THE COAL CONVERSION PROPOSAL SO THAT ACID DEPOSITION IS NOT INCREASED AS A RESULT OF THIS ENERGY STRATEGY.

The Department should join other states in advocating action by EPA on the above measures.

B. Action to Solicit Grant Money:

Title X, S. 932

The largest and most continuous potential funding source for acid rain research is the federal government. Under Title X of Senate Bill 932, the "Acid Precipitation Act of 1979", $56 million has been authorized over a ten year period to support acid rain activities. Title X directs a Federal Acid Deposition Task Force to cooperate with the states in studying the acid deposition problem, but it does not earmark any funds specifically for state activities. The DNR should make its needs known to the federal agencies (NOAA, Dept. of Agr., EPA) administering funds under this act.

Upper Great Lakes Regional Commission

An application has been filed with UGLRC for $37,300 which will be acted on at the June meeting of the Commission. This money, if granted, will be available for the 1980-81 fiscal year. Grants are not normally awarded for a second year on the same project.

Discussions with UGLRC staff at Superior indicate that the Commission is not willing to consider a tri-state application from Wisconsin, Michigan, and Minnesota. The main reason is the fact that Minnesota UGLRC and MPCA staff do not believe they need additional money.

Private Foundations

At lease one foundation (Johnson's Wax Foundation) had expressed interest in providing funds for acid rain research. Although our request to Johnson's Wax was recently denied, other private sources should be contacted to determine if there is an interest.

Region V, EPA 208 Funds

The Department has already applied for supplemental FY 1980 208 funds but no response has been received. The FY 1981 208 application will contain a proposed project for the North Central District Task Force.

Existing Resources

If other sources of funds do not materialize, the Department should consider reallocating existing resources to the acid deposition study. At a minimum, the Bureaus of Air Management, Water Quality, Research, I&E, Fish Management, and the North Central District should provide resources in the next work plans for acid deposition work.

E. Action to Coordinate Acid Deposition Efforts:

DNR Acid Deposition Task Force

After completing this report, the Task Force should continue to act in a coordinating capacity for a minimum of 1 year. Specifically, the Task Force should continue to perform the following duties:

(1) Review all DNR acid rain funding applications for research and surveys, and coordinate this review with the Department's established research review process.

(2) Review all DNR reports on acid rain research and surveys.

(3) Distribute new information on acid rain to appropriate bureaus and districts.

(4) Represent the Department at state and national meetings on acid rain.

(5) Respond to public requests for informational talks on acid rain.

(6) Advise the Department on other state and federal acid rain activities including any developments on emissions control.

Statewide Water Quality Advisory Committee

An Interagency Acid Deposition Advisory Subcommittee has been created from selected members of the Statewide Water Quality Advisory Committee to serve as an interagency coordinating body for the State of Wisconsin. Members of the subcommittee represent state and federal agencies that are either directly involved in acid rain research or may be impacted by the effects of acid rain. Members include representatives from the Departments of Natural Resources, Agriculture, Administration, Transportation; the University of Wisconsin Extension, Limnology Lab and Water Chemistry Department; the United States Forest Service, Fish & Wildlife Service, Geological Survey, Environmental Protection Agency; the State Geological Survey; Public Service Commission, Legislative Council, Soil Conservation Service, Economic Statistics and Cooperative Service, and the Air Quality Advisory Committee.

The function of the subcommittee is to coordinate acid rain activities among state agencies to avoid duplication of effort and to disseminate information between various state and federal agencies interested in the findings of acid rain research. The subcommittee will meet on the basis of need and will report its progress to the general membership of SWQAC when the latter group convenes.

The subcommittee is chaired by the chairman of DNR's Acid Deposition Task Force. It is recommended that the Interagency Acid Deposition Advisory Subcommittee continue to serve in the previously outlined capacity.

National Coordination

The "Acid Precipitation Act of 1979", Title X of Senate Bill 932 recently created a federal Acid Precipitation Task Force composed of one representative each from the Departments of Interior, Energy, Health and Human Resources, Commerce, State, Agriculture, the National Science Foundation, the Tennessee Valley Authority, the National Aeronautics and Space Administration, and the Council on Environmental Quality. The Task Force will be cochaired by the Administrators of the Environmental Protection Agency (EPA), Department of Agriculture, and the National Oceanic and Atmospheric Administration (NOAA). Four additional members shall be appointed by the President. There will also be four additional members consisting of the director of four national energy laboratories, Argonne, Battelle Northwest, Brookhaven and Oak Ridge.

The Task Force is directed to formulate a comprehensive plan to coordinate the efforts of Federal and State agencies, localities, university and other research and demonstration centers, and public and private corporations. $55 million has been provided to implement the plan.

It is recommended that the DNR Acid Deposition Task Force stay in close contact with the federal Task Force once it has been formed, in order to keep appraised of the federal comprehensive plan. Our needs for money should be clearly expressed to the federal task force.

The Director of DNR's Bureau of Air Management is a member of the State and Territorial Air Pollution-Program Administrators (STAPPA). It is recommended that Wisconsin coordinate its efforts to control emission through continued membership and input into STAPPA.

F. Treatment, Prevention, and Mitigation Options For Biotic Systems:

Lake Liming

Current estimates by the Department of Natural Resources' area fish managers put the cost of liming at over $165 per acre by truck if the lake is accessible and less than 100 acres. Aerial application of lime/water slurries will cost approximately $1 per gallon for the slurry and $500-$900/hour for the airplane depending on the size (B-26 delivering 9-1100 gallons costs approximately $900/hour flying cost and $500/day availability charges; B-17 or DC-4 aircraft delivering 1,600-2,200 gallons of slurry costs approximately $900/hour flying cost and $500/day availability charges). Helicopters are more expensive. Either type of aircraft is capable of depositing essentially 100% of its payload on a 20 acre lake. Repeated treatments will often be necessary due to reacidification in small seepage lakes. Periodic "shocking" of the lake's biota (caused by raising the pH of the water by up to five or six pH units) could adversely affect the plankton which may reduce fish food availability or otherwise upset the aquatic community. If a lake is already acidified, it may be contaminated with heavy metals leached from surrounding soils (especially aluminum) which can fowl gill membranes and interfere with oxygen transfer. Liming may not reduce aluminum concentrations enough to remove this threat.

The Department should reassess its existing lake liming projects and develop procedures which require proper calculation of the application rates, timing, and monitoring of any liming projects.

Watershed Liming

Watershed buffering capacity may eventually be depleted by acid deposition where soils are low in $CaCO_3$. In agricultural watersheds, the soils will probably already be limed regularly to enhance production of crops. Most of the highly susceptible lakes in northern Wisconsin are in forested watersheds which would be difficult to lime unless large aircraft could deposit limestone slurries in the lake watershed. Costs are unknown but are expected to be high.

Resistant Species Development

Some researchers are investigating the possibility of developing acid resistant fish or stocking fish that have naturally adapted to low pH environments. We do not recommend development of acid resistant fish because of the cost and the dangers of introducing genetic defects into the wild gene pool. Planting of naturally acid resistant fish strains should be considered in lakes where heavy metal concentrations are not above tolerable levels.

The task force does not believe lake or watershed liming or acid resistant fish planting should be carried out as a substitute for aggressive action in the area of emission reductions.

G. Data Management:

One of the major difficulties in evaluating the susceptibility of the nature and extent of the acid rain problem in Wisconsin is the lack of a coherent management of the data collected by the various programs. Where the data has been automated, there has been no attempt to make the different systems compatible.

Evaluation of the acid rain problem will require interfacing air quality, water quality, and biological and land use data on a statewide basis. This information will ultimately be needed on a regional and national level. Several major data bases have, or are, in the process of being established (Brookhaven National Laboratory, EPA-Duluth, EPA-Washington, EPRI, USGS). The Department should assign one full time employee to manage the existing data related to acid deposition in Wisconsin and to begin the task of interfacing Wisconsin's data with national assessment programs. As more data is generated from Wisconsin projects, it will become increasingly difficult to stay abreast of the latest results unless this data is properly managed. This is not a trivial task.

It is recommended that the data base be maintained on the Madison Area Computing System (MACC) because this system is larger, flexible, has many "canned" programs, can be accessed by the Districts, and is used by the Statistical Laboratory. Consideration should be given to encouraging MACC to use the Scientific Information Retrieval (SIR) computer data management system. This is the same system being used by the University of Minnesota who will be managing the data generated by EPA-Duluth (this data will also include much of the WDNR data).

Under no circumstances should the Department expend much staff time entering this data on STORET. This data retrieval system is not flexible enough to deal with the data management problems we anticipate on this project.

8. CONCLUSIONS

A. Wisconsin Susceptibility:

The State of Wisconsin has more aquatic resources susceptible to acidification from acid deposition than any other state in the eastern United States. Because of the geology of northern Wisconsin, thousands of our lakes are small, naturally infertile, seepage lakes on soils that apparently contain very little buffering capacity. These characteristics make northern Wisconsin's lakes very similar to the thousands of lakes in Norway that have already lost their fish populations due to acidification as a result of acid deposition.

Normal levels of acidity were measured in Wisconsin precipitation during the early 1970's. In contrast, rain and snow monitoring in northern Wisconsin from Fall, 1979 to present yielded pH measurements ranging from ten to one hundred times the acidity of "normal" rain.

Given this regime in Wisconsin---susceptibility plus acid precipitation---it is only a matter of time before we experience some damage. The question is "how soon will we experience this damage if conditions remain unchanged?" In this context...plus the unique, complex nature and origin of the problem, the rapidity of acidification in softwater lakes, and the dim prospects for lake recovery once acidified...acid rain is very likely the greatest freshwater threat we face in Wisconsin at this time.

We expect deposition in Wisconsin to become more acidic as the country continues to shift from its current reliance on foreign oil to use of domestic coal reserves as its primary source of energy unless emissions are controlled. Electric power plant coal consumption alone is expected to rise from our present national rate of 820 million tons per year to approximately 1,250 million tons per year by 1990.

Even with better air pollution control technology mandated by new source performance standards for all new coal-fired electrical generation capacity, a significant increase in acid deposition precursors can be expected.

In view of these predictions, the State of Wisconsin needs answers to the following questions:

(1) How susceptible to acidification are Wisconsin's terrestrial and aquatic resources?

(2) Have they already been affected by acid deposition?

(3) If so, to what extent; if not, how much time do we have to prevent damage?

(4) To what extent is Wisconsin responsible for its own acid deposition problem?

(5) How do Wisconsin's emissions affect other states and how does the long-range transport of pollutants affect Wisconsin?

B. General Recommendations:

(1) The Department of Natural Resources should continue to be the lead state agency pertaining to acid rain research.

(2) The Department should submit a request for $445,000 in the next biennial budget to fund in-house short-term research and contract appropriate studies. The Department should continue to pursue federal and private grants for long-term acid rain research.

(3) The Department's Acid Deposition Task Force should continue to function for at least 1 year, in a coordinating capacity for various bureau and district activities, and as a review body for funding requests to granting agencies.

(4) The Department should encourage other agencies to conduct acid rain research, but ensure that these studies are coordinated through the Statewide Water Quality Advisory Committee.

(5) The Department should continue to pursue immediate emission control action on the part of the U.S. EPA to reduce acid deposition.

(6) The Department should work closely with the Public Service Commission, to pursue mechanisms that would require utilities to conduct acid rain research as part of the power plant siting process.

(7) The Department should provide periodic press releases to the public to keep them informed on acid rain research. Because of poor communications in the past year, the news media has occasionally overstated the potential problem in Wisconsin and has erroneously implied that fish kills have already resulted in Wisconsin due to acid rain. This overstatement of facts has caused concern in the tourism industry and among people who frequent northern Wisconsin's recreational areas. The public must be made aware of the potential impact of acid rain on the resources of our state, but must also be made aware that lake acidification is a relatively gradual process that may occur over several decades, not overnight. The Department's present role is to define how great the potential impact of continued acid deposition could be on our resource, and to seek action to reduce acid deposition before our resources are damaged.

C. Acid Deposition Project Objectives:

Goal Statement - To protect the terrestrial and aquatic resources of the State of Wisconsin from potential damage due to the effects of acid deposition.

Objectives

(1) To determine acid loading rates to Wisconsin.

(2) To determine the approximate contribution of Wisconsin emissions vs. long-range transport of pollutants.

(3) To assess the susceptibility of Wisconsin's resources to continued acid deposition.

(4) To determine approximate time frames for potential damage to Wisconsin.

(5) To insure that air pollution control measures will be equitably applied among the eastern states according to each state's contribution to the problem.

(6) To develop appropriate control measures for Wisconsin's contribution to the problem within the authority of the Clean Air Act and Wisconsin statutes and administrative codes.

(7) To determine whether there are any effective means of reversing acidification damage to aquatic or terrestrial ecosystems.

(8) To accurately inform the public of the potential or actual damage to Wisconsin's resources based on the interpretation of sound data.

(9) To cooperate with, and involve, other state and federal agencies and the private sector in the study and prevention of acid deposition.

6. LITERATURE CITED

Adams, D.F., 1979. Sulfur gas emissions from flue gas desulfurization sludge ponds. J.APCA. 29:963-968.

Abrahamsen, G., R. Horntvedt, and B. Tveita, 1976. Impacts of acid precipitation on coniferous forest ecosystems. pp. 991-1009. In L.S. Dochinger and T.A. Seliga (eds.) Proc. First Int. Symp. on Acid Precipitation and the Forest Ecosystem. USDA Forest Service Gen. Tech. Rep. NE-23. Upper Darby, PA.

Almer, B., W. Dickson, C. Ekstrom, E. Hornstrom, and U. Miller. 1976. Effects of acidification on Swedish lakes. Ambio.

Altshuller, A.P., 1979. Model predictions of the rates of homogenous oxidation of sulfur dioxide to sulfate in the troposphere. Atmos. Environ. 13:1653-1661.

American Fisheries Society. 1979. A review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, Am. Fish. Soc., Wash., DC. 313 pp.

Annual Report of Cooperative Regional Projects, January 1 to December 31, 1978. 1979. Project: NC-141- NADP, Chemical changes in atmospheric deposition and effects on land and surface waters.

Appel, B.R., E.L. Kothny, E.M. Hoffer, G.M. Hidy and J.J. Wesolowski, 1978. Sulfate and nitrate data from the California Aerosol Characterization Experiment (ACHEX). Environ. Sci. Technol. 12:418-425.

Atkins, D.H.F., R.A. Cox and A.E.Y. Eggleton. 1972. Photochemical ozone and sulfuric acid formation in the atmosphere over southern England. Nature, Land. 235:372-377.

Barnes, R.A., 1979: The Long Range Transport of Air Pollution. A review of the European Experience, Journal of the Air Pollution Control Association, 29, 1219-1234.

Barrie, L. and H.W. Georgii. 1976. An experimental investigation of the absorption of sulfur dioxide by water drops containing heavy metals. Atmos. Environ. 10:743-749.

Beamish, 1976. Acidification of lakes in Canada by acid precipitation and the resulting effect on fishes, water, air, soil pollution. 6:501-514.

Beilke, S. and G. Gravenhorst, 1978. Heterogeneous SO2-oxidation in the droplet phase. Atmos. Environ. 12:231-239.

Benson, S.W., 1978. Thermochemistry and kinetics of sulfur-containing molecules and radicals. Chem. Rev. 78:23-35.

Bracewell, J.M. and O. Gall, 1967. Catalytic oxidation of sulfur dioxide in solution at concentrations occurring in fog droplets. Proc. Symp. on Physico-chemical Transformation of Sulfur Dioxide Compounds in the Atmosphere and Formation of Acid Smogs. Mainz, Germany.

Brimblecombe, P. and D.I. Spedding, 1974. Catalyzed oxidation of micromolar aqueous sulfur dioxide. Atmos. Environ. 8:937-945.

Bush, D.M., 1980. The potential impact of acid precipitation on Wisconsin's fisheries. Fish Management Report 105, Wisconsin Department of Natural Resources.

Calvert, J.G., 1976. Hydrocarbon involvement in photochemical smog formation in Los Angeles atmosphere. Environ. Sci. Technol. 10:256-262.

Calvert, J.G. and R.D. McQuigg, 1975. Computer simulation of the rates and mechanisms of photochemical smog formation. J. Chem. Kinet., Symp. 1:113-154.

Calvert, J.G., F. Su, J.W. Bottenheim and O.P. Strausz, 1978. Mechanism of the homogenous oxidation of sulfur dioxide in the troposphere. Atmos. Environ. 12:197-226.

Cogbill, C.V. and Likens, G.E. 1974. Acid precipitation in the northeastern U.S. Water Resources Research 10:1133-37.

Cogbill, Charles V. 1976. The history and character of acid precipitation in eastern North America. In: Dochinger, L.S. and T.A. Seliga (eds.) Proc. First Int. Symp. on Acid Precipitation and the Forest Ecosystem. USDA Forest Service Gen. Tech. Rep. NE-23. pp. 363-370.

Cowling, E.B., and F.A. Wood. 1976. The changing chemistry of precipitation and its implications for forest growth and productivity. pp. 172-180. In D.M. Baker and M.A. Fosberg (eds.) Proc. Fourth National Conf. on Fire and Forest Meteorology. USDA Forest Service General Tech. Rep. RM-32. Fort Collins, CO.

Cowling, E.B. 1978. Effects of acid precipitation and atmospheric deposition on terrestrial vegetation. pp. 44-63. In Galloway, J.N., Cowling, E.B., Gorham, E., and McFee, W.W. A national program for assessing the problem of atmospheric deposition (acid rain). A report to the council on environmental quality. NADP. NC-141.

Davies, T.D., 1979. Dissolved sulfur dioxide and sulfate in urban and rural precipitation (Norfolk, U.K.). Atmos. Environ. 13:1275-1285.

Derwent, R.G., A.E.J. Eggleton, M.L. Williams and C.A. Bell, 1978. Elevated ozone levels from natural sources. Atmos. Environ. 12:2173-2177.

Dochinger, L.S., and T.A. Seliga. 1976. Proceedings First International Symposium on Acid Precipitation and the Forest Ecosystem. USDA Forest Service, Gen. Tech. Rep. NE-23, Northeast. For. Exp. Sta., Upper Darby, PA. 1079 pp.

Eggleton, A.E.J. and R.A. Cox, 1978. Homogeneous oxidation of sulfur compounds in the atmosphere. Atmos. Environ. 12:227-230.

EIFAC. 1968. Water quality criteria for European fresh water fish. Report on extreme pH values and inland fisheries. Tech. Paper No. 4. Working party on water quality criteria for European fresh water fish, European Inland Fisheries Advisory Commission, FAO Rome. 24 pp.

Eisenreich, S.J., P.J. Emmling, and A.M. Beeton. 1977. Atmospheric loadings of phosphorus and other chemicals to Lake Michigan. J. Great Lakes Res. 3:291-304.

Elroy, M.B., S.C. Wofsy and N. Dak Sze, 1980. Photochemical sources for atmospheric HgS. Atmos. Environ. 14:159-163.

Enger, L. and U. Hogstrom, 1979. Dispersion and wet deposition of sulfur from a power plant plume. Atmos. Environ. 13:797-810.

"EPRI seeks to unlock 'mystery' associated with acid rains." 1979. Air/Water Pollution Report. 17(36):386.

Forrest, J., R. Garber and L. Newman, 1979. Formation of sulfate, ammonium and nitrate in an oil-fired power plant plume. Atmos. Environ. 13:1287-1297.

Freiberg, J., 1974. Effects of relative humidity and temperature on iron-catalyzed oxidation of SO_2 in atmospheric aerosols. Environ. Sci. Technol. 8:731-734.

Friend, J.P., 1979. A review of the atmospheric chemistry related to precipitation. Proc: Advisory Workshop to Identify Research Needs on the Formation of Acid Precip. EPRI AE-1074, WS-78-98, Workshop Report.

Galloway, J. and G. Parker 1979. Sulfur Deposition in the eastern U.S. In: Mac Cracken, M.C. The multistate atmospheric power production pollution study - MAP3s, progress report for FY 1977 and FY 1978. UCRL-52440. Livermore, Calif.: University of California, Lawrence Livermore Laboratory, July. pp. 124-138.

Ganor, E., E.H. Steinberger and A. Donagi, 1977. Comparison of ozone concentration in Tel-Aviv and Jerusalem. Proc. Eighth Sci. Conf., IES, pp. 230-241.

Glass, G., ed. 1979. Impacts of air pollutants in wilderness areas of northern Minnesota. Final draft copy. Duluth, Minn.: U.S. Environmental Protection Agency, Environmental Research Lab. pp. 69-73.

Gorham, E.C. 1978. The effects of acid precipitation upon aquatic and wetland ecosystems. p. 41. In: Galloway, J.N., Cowling, E.B., Gorham, E., and McFee, W.W. A national program for assessing the problem of atmospheric deposition (acid rain). A report to the council on environmental quality. NADP, NC-141.

Graedel, T.E., 1977. The oxidation of ammonia, hydrogen sulfide and methane in non-urban tropospheres. J. Geophys. Res. 82:5917-5922.

Haines, B., and R.G. Best. 1976. The influence of an endomycorrhizal symbiosis of nitrogen movement through soil columns under regimes of artificial throughfall and artificial acid rain. pp. 961-962. In L.S. Cochinger and T.A. Seliga (eds.) Proc. First International Symposium on Acid Precipitation and the Forest Ecosystem. USDA Forest Service Gen. Tech. Rep. NE-23. Upper Darby, PA.

Harker, A.B., L.W. Richards and W.E. Clark, 1977. The effect of atmospheric SO_2 photochemistry upon observed nitrate concentrations in aerosols. Atmos. Environ. 11:87-92.

Harrison, H., T.V. Larson and P.V. Hobbs, 1976: Oxidation of sulfur dioxide in the atmosphere: a review., Proc., Int'l Conf. on Environmental Sensing and Assessment. 23-1, 1-7.

Hegg, D.A. and P.V. Hobbs, 1979. Homogeneous oxidation of sulfur dioxide in cloud droplets. Atmos. Environ. 13:981-987.

Hegg, D.A. and P.V. Hobbs, 1980. Measurements of gas-to-particle conversion in the plumes from five coal-fired electric power plants. Atmos. Environ. 14:99-116.

Heicklen, J., 1976. Atmospheric Chemistry. Academic Press, N.Y., pp. 274-275.

Hindawi, I.J., J.A. Rea, and W.L. Griffis. 1980. Response of bush bean exposed to acid mist. Amer. J. Bot. 67(2): 168-172.

Hitchcock, D.R., L.L. Spiller and W.E. Wilson, 1980. Sulfuric acid aerosols and HCl release in coastal atmospheres: evidence of rapid formation of sulfuric acid particulates. Atmos. Environ. 14:165-182.

Hrafi, R.G., D.R. Keeney and L.M. Walsh, 1972. Nitrogen and sulfur in precipitation and sulfur dioxide in the atmosphere in Wisconsin. J. Environ. Quality, Vol. 1, no. 2.

Hoffman, M.R. and B.C. Lim, 1979. Kinetics and mechanism of the oxidation of sulfide by oxygen: catalysis by homogeneous metalphtalocyanine complexes. Environ. Sci. Technol. 13:1406-1414.

Homolya, J.B. and C.R. Fortune, 1978. Measurement of the sulfuric acid and sulfate content of particulate matter resulting from the combustion of coal and oil. Atmos. Environ. 12:2511-2514.

Homolya, J.B. and J.L. Cheney, 1978. An assessment of sulfuric acid and sulfate emissions from the combustion of fossil fuels. Workshop Proceedings on Primary Sulfate Emissions from Combustion Sources, Vol. 2:3-12, 1978. EPA-600/9-78-0206.

Houston, D.B. 1974. Responses of selected Pinus strobus L. clones to fumigations with SO_2 and O_3.

Houston, D.B., and L.S. Dochinger. 1977. Effects of ambient air pollutants on cone, seed, and pollen characteristics in eastern white and red pine. Environ. Pollut. 12(1977).

Hunter, S.C. and P.K. Engel, 1978. Sulfur oxides emissions from boilers, turbines and industrial combustion equipment. Workshop Proc. Primary Sulfate Emissions from Comb. Sources, Vol. 2, pp. 13-52, EPA-600/9-78-020b ESRL, Research Triangle Park.

Johnson, A.H. 1979. Evidence of acidification of headwater streams in the New Jersey Pinelands. Science. 206:834-835.

Johnsson, B., and R. Sundberg. 1972. Has the acidification by atmospheric pollution caused a growth reduction in Swedish forests? Research Note No. 20. Department of Forest Yield Research, Royal College of Forestry, Stockholm, Sweden. 48 pp.

Kobinger, N.P., 1975. Mineral cycling and productivity in an upland deciduous forest: soils and methodology. C.W.H. Field Bulletin. 8:2. pp. 8-15.

Kotar, J. 1978. Effects of low-level SO_2 emissions from a modern smelter on tree growth. Abstract Bulletin ESA V. 59(2):64.

Kratky, B.A., E.T. Fukunaga, J.W. Hylin, and R.T. Nakano. 1974. Volcanic air pollution: Deleterious effects on tomatoes. J. Environ. Qual. 3:138-140.

Lavery, T.F., G.M. Hidy, P.K. Mueller and K.K. Warren, 1979: Assessment of regional air pollution over the eastern United States. Environmental Research and Technology, Inc.

Lewis, W.M., Jr. and Grant, M.C. 1980. Acid precipitation in the western United States. Science. 207:176-177.

Lazberg, E.A., F.H. Hunenik and O.A. Ottersen, 1979. Sulfate and nitrate mixing ratios in the vicinity of the tropopause. Atmos. Environ. 13:1299-1304.

Liberti, A., D. Brocco and M. Possanzini, 1978. Adsorption and oxidation of sulfur dioxide on particles. Atmos. Environ. 12:255-261.

Liegel, E. and T. Koehler. 1980. Wis. plant analysis trends during the 70's. In proceedings of the 1980 Fertilizer, Aglime and Pest Management Conference. Vol. 19:184-189. College of Agriculture and Life Sciences, University of Wisconsin-Madison.

Lijestrand, H.M. and Morgan, J.J. 1978. Chemical composition of acid precipitation in Pasadena, California. Environmental Science and Technology. 12:1271-73.

Likens, G.E., R.F. Wright, J.N. Galloway and T.J. Butler, 1979: Acid rain, Scientific American, 241, October, 43-51.

Likens, G.E., Borman, F.H. and Johnson, N.M. 1972. Acid rain. Environment. 14(2):34-40.

Likens, G.E. and Borman, F.H. 1974. Acid rain: a serious regional environmental problem. Science. 184:1176-79.

- 45 -

Likens, G.E., 1976. Hydrogen ion input to the Hubbard Brook experimental forest, New Hampshire, during the last decade. Water, Air and Soil Pollution. 6:435-45.

Likens, G.E., 1976. Acid precipitation. Chemical and Engineering News 54 (22 November): 29-44.

Lillie, R.A. and J.W. Mason. 1980. pH and alkalinity of Wisconsin lakes. Department of Natural Resources Publication.

Lyons, W.A., J.C. Dooley, Jr., and K.T. Whitby, 1978: Satellite Detection of Long-range Pollution Transport and Sulfate Aerosol Hazes, Atmospheric Environment, 12, 29-31.

Magnuson, J. 1980. Pers. Comm. U. of Wisconsin Limnology Lab.

Miller, D.F., 1978. Precursor effects on SO_2 oxidation. Atmos. Environ. 12:273-280.

Morgan, J.J. and H.M. Liljestrand, 1980. Measurement and interpretation of acid rainfall in the Los Angeles Basin. Calif. Instit. Technol., Report No. AC-2-80.

Mount, Donald I. 1973. Chronic effect of low pH on fathead minnow survival, growth and reproduction. Water Res. 7:987-993.

NADP field measurements reported by U.S. Forest Service North Central Forest Experiment Station. 1980.

National Academy of Sciences, Committee on Sulfur Oxides, 1978: "Sulfur Oxides".

Natural Resources Defense Council. 1978. Respirable particles, the impact of airborne fine particulates on health and the environment.

Newman, L., 1979. General considerations on how rainwater must obtain sulfate, nitrate and acid. Presented before the American Chemical Society, Honolulu, Hawaii.

Orel, A.E. and J.H. Seinfeld, 1977. Nitrate formation in atmospheric aerosols. Environ. Sci. Technol. 11:1000-1007.

Pantar, R. and R.D. Pancharo, 1980. Alkyl sulfonic acids in atmosphere. Atmos. Environ. 14:149-151.

Pastor, J. and J.G. Bockheim. 1980. Distribution and cycling of nutrients in an aspen-mixed hardwood ecosystem in northern Wisconsin. Manuscript to be submitted to Ecol. Monog.

Penkett, S.A., B.M.R. Jones, K.A. Brice and A.E.J. Eggleton, 1979. Importance of atmospheric ozone and hydrogen peroxide in oxidizing sulfur dioxide in cloud and rainwater. Atmos. Environ. 13:123-137.

Penkett, S.A., B.M.R. Jones and A.E.J. Eggleton, 1979. A study of SO_2 oxidation in stored rainwater samples. Atmos. Environ. 13:139-147.

Penkett, S.A. and J.A. Garland, 1974. Oxidation of sulfur dioxide in artificial fogs by ozone. Tellus 26:294-290.

Perhac, R.M. 1980. Testimony before subcommittee on environmental pollution. U.S. Congress. March 19, 1980. p. 16.

Pough, F.H. 1976. Acid precipitation and embryonic mortality of spotted salamanders, Ambystoma maculatum. Science. 192:68-70.

Quarles, J. 1973. Testimony at hearings before the subcommittee on public health and the environment. House of Rep. No. 93-67.

Ranlund, D.Ed. 1973. Forest pest conditions in Wisconsin. Annual reports 1972 and 1973. Wis. Dept. of Natural Resources, Madison, WI.

Richardson, C.J. and Marva, G.E. Marva, 1978. The chemical composition of atmospheric precipitation from selected stations in Michigan. Water, Air and Soil Pollution. 6:388-393.

Schaefer, M. (ed.) 1979. Acid rain. Environmental protection agency, research summary. EPA-600/8-79-028.

Schofield, C. 1980. Personal Communication.

Scott, B.C. 1978: Parameterization of sulfate removal by precipitation. J. Appl. Meteor., 17, 1375-1389.

Scott, B.C. and N.S. Laulainen, 1979: On the concentration of sulfate in precipitation. J. Appl. Meteor. 18: 138-147.

Scott & Cattel, 1979. Vapor pressure of ammonium sulfates. Atmos. Environ. 13:307.

Shaw, B. 1980. Pers. Comm. U. of Wisconsin Stevens Point.

Shaw, R.S. 1979. Acid precipitation in Atlantic, Canada. Environmental Science and Technology. 13:[illegible].

Sheih, C.M., M.L. Wesely and B.B. Hicks, 1979: Estimated Dry deposition velocities of sulfur over the Eastern United States and Surrounding regions. Atmospheric Environment, 13, 1361-1368.

Shriner, D.S. 1976. Effects of simulated rain acidified with sulfuric acid on host-parasite interactions. pp. 919-925. In L.C. Dochinger and T.A. Seliga (eds.) Proc. First Int. Symp. on Acid Precipitation and the Forest Ecosystem. USDA Forest Service Gen. Tech. Rep. NE-23. Upper Darby, PA.

Simpkins, W.W. and D.M. Nicholson. 1980. Interrelationship between drift composition and water chemistry in Forest County, Wisconsin. Symposium of Geological Society of America.

Spicer, C.W., D.W. Joseph, P.R. Stickael and G.F. Ward, 1979. Ozone sources and transport in the northeastern United States. Environ. Scie. Technol. 13:975-985.

Steinberger, E.H. and Y. Gehner, 1977. Photochemical ozone formation in the atmosphere over southern England. Nature, Lond. 241:341-342.

Steinberger, E.H. and E. Ganor, 1980. High ozone concentrations at night in Jerusalem and Tel-Aviv. Atmos. Environ. 14:221-225.

Stensland, G. 1979. Acid Precipitation in Central Illinois. In: Mac Cracken, M.C. The multistate atmospheric power production pollution study - MAP3S, progress report for FY 1977 and FY 1978. UCRL-51-2045. Livermore, Calif.: University of California, Lawrence Livermore Laboratory, July. pp. 135-144.

Stern, A.C., 1976. Air Pollution, third edition, Vol. 1, Academic Press, N.Y.

Suchman, D. and D.W. Martin, 1976: Wind sets from SMS images: An assessment of quality for GATE. J. Appl. Meteor., 15, 1165-1278.

Sweers, P.H. and Whelpdale, D.W. 1975. Acid precipitation in Canada. In Proceedings of the First International Symposium on Acid Precipitation and the Forest Ecosystem, pp. 4-21. GTR-NE-23. Upper Darby, Pa.: U.S. Forest Service.

Tabatabai, M.A. and Laflen, J.M. 1976. Nutrient content of precipitation over Iowa. Water, Air and Soil Pollution. 6:361-373.

Talbot, R. 1979. Pers. Comm. U. of Wisconsin Water Chemistry Department.

Tamm, C.O. 1976. Acid precipitation: Biological effects in soil and on forest vegetation. Ambio 5:235-238.

Tibbitts, T.W., D.M. Olszyk, L.L. Knudson, R.R. Coltman, H.H. Prank, and D. F. Karnosky. 1977. Plant damage. In Documentation of Environmental Change Related to the Columbia Electric Generating Station, 11th Semi-Annual Report, Spring-Summer 1977. Institute for Environmental Studies, Univ. Wisconsin-Madison. IES Report No. 92.

"Tracking the clues of acid rain". 1979. EPRI Journal 4(8):20-24.

Trojnar, J.R. 1977. Egg hatchability and tolerance of brook trout (Salvelinus fontinalis) fry at low pH. Journ. Fish. Res. Bd. of Canada. 34(4):262-266.

Tsunogai, S., 1971. Oxidation of sulfite in water and its bearing on the origin of sulfate in meteoric precipitation. Geochem J. 5:175.

U.S. Environmental Protection Agency. 1977. Quality criteria for water. Office of water and hazardous materials. U.S. Environmental Protection Agency, Washington, DC. 256 pp.

U.S. Environmental Protection Agency. 1978. Health effects considerations for establishing a standard for inhaled particulates. Research Triangle Park, p. 10.

Weiss, R.E., A.P. Waggoner, R.J. Charlson, and N.C. Ahlquist. 1977. Sulfate aerosol: its geographical extent in the midwestern and southern United States. Science, 1975: 979-981.

Winkler, E.M., 1973. Properties, durability in man's environment. Springer-Verlag, New York-Vienna, 250 pp. Proceedings of First International Symposium on Acid Precipitation and Forest Ecosystems. USDA Forest Service Gen. Tech. Report. NE-23.

Wood, T., and F.H. Bormann. 1974. The effects of an artificial acid mist upon the growth of Betula alleghaniensis Brit. Environ. Pollut. 7:259-268.

Wood, T., and F.H. Bormann. 1975. Increases on foliar leaching caused by acidification of an artificial mist. Ambio. 4:169-171.

Wood, T., and F.H. Bormann. 1977. Short-term effects of a simulated acid rain upon the growth and nutrient relations of Pinus strobus L. Water, Air Soil Pollut. 7:479-488.

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Mr. MARTINI. Wisconsin is a State blessed with extensive aquatic resources. We have one of the highest concentrations of lakes in the world, one of the three highest in the world. These lakes are the base of a very significant tourism industry. We are very concerned about the potential effects of acid deposition on aquatic as well as terrestrial resources.

About a year and a half ago we began to study the effects of land use on lake water quality in the north central part of the State. We had perceived some deterioration. We were not certain what the causes were.

As we began studying this problem, we realized that a more significant threat from acid deposition was probably facing the Wisconsin lake ecosystems. We felt that it was important to try to assess not only the susceptibility of our aquatic systems, but also to determine what the time frame was for possible effects, as well as try to estimate the impact on the economy and the impact on the ecological balance in northern Wisconsin.

This was a tall order. We had very little data on which to rely.

When we began assessing susceptibility we had six criteria in mind:

First, we wanted tc determine approximately what the geological and soil effects of watersheds would be on a lake's susceptibility to acidification. We knew from the literature that watersheds that are composed primarily of sandy soils with very little calcium carbonate would be much more susceptible to acidification than those that had a large amount of dolomite or lime, like we have in southern Wisconsin. In northern Wisconsin we have very little calcium carbonate or buffering capacity in our soil. We selected a number of lakes and found that the majority of our lakes were actually situated on soils deficient in buffering capacity.

Bedrock geology is also important. We are underlain by granitic bedrock which has very little calcium carbonate. Therefore, it has very little ability to add buffering capacity to the soil through the weathering process.

The large concentration of lakes meant that our lakes were fairly small in watershed size. Lakes with small watersheds are more susceptible than larger watersheds because they have less opportunity for the precipitation to be buffered between the time it falls from the atmosphere and the time that it actually enters the lake. Therefore, our small watersheds made the lakes in northern Wisconsin much more susceptible.

We also had a large concentration of seepage lakes in northern Wisconsin. Seepage lakes are probably due to the geologic and glacial conditions which we have in northern Wisconsin. The effects of the glacier have created a large number of seepage lakes which have no inlets or outlets and are largely dependent on runoff for their recharge in addition to ground water recharge. This makes a lake more susceptible because rainfall is not getting the benefit of contact with large amounts of soil from the watershed to add buffering capacity.

We also knew that our lakes were already low in productivity. We had low concentrations of calcium carbonate, which is a constituent that can provide buffering capacity to the water and neutralize some of the acid deposition. We had low pH's already in

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many of our lakes, making them more susceptible to further acidification.

The next step after assessing susceptibility was to determine what was falling from the atmosphere. We had very little data on which to rely, so we began collecting data on precipitation in northern Wisconsin approximately 1 year ago. Since then we have determined that rainfall in northern Wisconsin is approximately 10 times more acidic than normal rainfall, and individual storms have been measured as high as 100 times as acidic as normal rainfall.

We know that this is the approximate range of precipitation acidity that they are receiving in other parts of the world that have experienced acidified lakes and loss of their fishery populations. We are very concerned, inasmuch as we know that our systems are susceptible, that damage is probably inevitable in northern Wisconsin. One of the things that we do not know is how long it is going to take for lakes or other aquatic or terrestrial ecosystems to be affected. That is one of the things we are in the process of determining now.

After we determined susceptibility, we began trying to study the various ecological components that depend on aquatic resources or could be affected by precipitation. We began studying the fish in northern Wisconsin lakes last summer in cooperation with the Environmental Protection Agency and the U.S. Fish and Wildlife Service. As yet, the data has not been analyzed. We have looked at some of the raw data but have not subjected it to statistical analysis or computer analysis.

Of the 12 lakes we picked to study for fishery populations, 6 of the 12 being susceptible and 6 nonsusceptible control lakes, we found that there was conspicuous absence of cyprinid fishes; that is minnows, in the 6 susceptible lakes we had selected. Cyprinid fishes or minnows are among the most susceptible varieties of fish. They would be expected to be affected first if any fish were affected in northern Wisconsin. Other species that we are concerned about are walleyes and smallmouth bass, which also show a very high susceptibility rating.

We are not certain whether this absence of minnows in these six susceptible lakes indicates effects by acid deposition. It could simply be a reproductive failure due to a number of other factors. We do know that we used the same gear and the same amount of effort in the susceptible lakes as we did in the nonsusceptible lakes. We found plenty of minnows in the nonsusceptible lakes.

Senator NELSON. Mr. Martini, unfortunately, the President's new youth program markup legislation is in my subcommittee in the Human Resources Committee. I have to chair that markup. We are attempting to get that bill completed during this session.

At the time we scheduled this hearing I did not realize that we were going to have the markup on the President's youth bill this morning. Therefore, I am going to have to leave for the time being. If I can get somebody else to handle some of that, I will be back.

Let me say it is good to have this background in the record. However, we do have 12 witnesses, so I am going to ask all witnesses to address the question of the economic impact of acid rain. That is one aspect of this problem that so far as I know has not been addressed, at least by any hearings in the Congress.

It is important that we develop an understanding in the Congress and among the public of what we are talking about in economic terms, because things are going to have to be done that cost money to eliminate the introduction into the environment of the sulfur oxides and the nitrogen oxides which are causing the acid rain. There will be a cost factor involved in that aspect of the program.

Therefore, it is very important that we also see what the cost factor is if we fail to address the problem. In all of these issues this cost-benefit ratio question is raised.

For example, the water pollution control program has cost billions of dollars and will hit $100 billion one of these days. However, the cost of not cleaning up the water in the country is much higher than the cost of cleaning it up.

I suspect that the cost of not abating this problem will be far greater than the cost of resolving it. We cannot afford the disaster that will occur, from an environmental quality standpoint and from an economic standpoint if the freshwater assets of this country are destroyed, plus whatever implications there are in reducing forestry growth, affecting agriculture, fisheries, and so forth. Therefore, it is very important that this record address the question of the economic cost of acid rain.

Inasmuch as we have 12 witnesses and a number of witnesses have prepared statements, we will print all prepared statements in full in the record and I would hope that the witnesses would zero right in on the economic costs as they view it of the acid rain problem.

Senator Mitchell will preside now.

Mr. MARTINI. The reason I was discussing the potential effect on fisheries, especially game fish, is that Wisconsin leads the Nation in nonresident fishing license sales of any State in the Union. Approximately 1.9 million nonresident fishing licenses are sold in Wisconsin every year, significantly more than any other State.

One of the things that makes our tourism industry so strong is it is based in fishing and aquatic resource recreation. Our tourism industry in Wisconsin is estimated at approximately $5 billion annually. Fishing and aquatic-based recreation is one of the keystones of that industry.

We know that a number of nonresidents come to northern Wisconsin specifically for the fishing and spend a tremendous number of angler days in northern Wisconsin pursuing some of the most susceptible fishes, the walleye and the smallmouth bass. Many of the other fish that are not as susceptible to acidification, such as the muskie, are directly dependent on forage fishes such as the minnows and other fishes that may be very susceptible to acid deposition. Therefore, it is a significant part of the economy in the State of Wisconsin.

Other people from Wisconsin will discuss the dependence on aquatic-based recreation in other testimony.

We have no information to indicate what effect acid deposition may have on our foresty industry, which is another major industry in Wisconsin. We know that in the northeastern part of the United States research is being undertaken on the effects of acid deposition on the growth of conifers, especially red pine and Christmas

tree production which are significant parts of our foresty industry in northern Wisconsin.

We feel there is some alleged research that indicates that acid rain may intensify the effects of various fungal diseases and these types of trees could eventually have reduced growth rates due to interactions of acid deposition in the soil, reducing the growth rate of trees and in some cases reducing germination and growth of the seedlings.

Wisconsin has a thriving paper industry. We utilize our northern forests for pulp for that industry. We are very deficient in the conifer-type pulp. This would be something we are trying to develop in the future—more dependence on Wisconsin conifer pulp for the pulpwood industry. If it is affected by acid deposition, that would seriously impair our ability to grow our own natural resources for this important industry.

We know that wild rice is affected by sulfate concentration above 50 parts per million. We know that very few northern Wisconsin lakes have sulfate concentrations above 50 parts per million, but we also know that in Scandanavia a number of lakes have increased from a range of about 20 milligrams per liter—parts per million—of sulfate up to about 300 parts per million of sulfate. If the same pattern occurs in northern Wisconsin, we could lose the wild rice industry, which may not be very economically important but it is culturally important to a number of Indian tribes in northern Wisconsin.

Tourism and the recreation industry in northern Wisconsin is very important. In Vilas County 28 percent of all employment is directly related to tourism industries. A very significant part of the economy in northern Wisconsin depends on tourism.

Agriculture in north central Wisconsin is based on dairy farming. A large percentage of the food and forage for these dairy cows is grown on soils that require large amounts of agricultural lime to carry out farming. Just the ASCS cost of lime in one county alone last year was $90,000. This is a very small percentage of the total liming that was done in that county.

We anticipate that with additional acidification this lime will be leached beyond the root zone or neutralized and provide increased cost to the dairy farmer, especially the small family farm which is dependent on growing its own forage in soils that are deficient in lime.

Potatoes are another important crop in northern Wisconsin. We have seen some indication that potatoes could be one of the more susceptible agricultural crops due to the research that has been done at the Corvallis EPA lab.

Our ground water resources in northern Wisconsin support irrigated agriculture as well as the drinking water sources of most of northern Wisconsin. We have seen that in Norway ground water acidification has caused erosion of pipe fixtures and plumbing and has also resulted in elevated concentrations of heavy metals in drinking water, which could be a serious economic impact on those people who rely on these aquifers for their drinking water sources.

Our Department of Transportation in Wisconsin has determined that corrosion of culverts, structural steel, concrete, and other building materials in northern Wisconsin corrodes and erodes sig-

nificantly faster than it does in other parts of the State and other parts of the country. They postulate that acid deposition could have a direct effect on it. They are beginning to study the total economic cost to the State from erosion of structural materials right now, but we have no dollar figures involved.

Lake liming has been suggested as a means of reducing the affects of acid deposition in aquatic ecosystems.

The State of Wisconsin has had considerable experience with this technique dating back to the early 1950's. Although we know lakes can be neutralized by the addition of lime (in various forms), there are a number of significant problems with this technique as a cure for the effects of acid deposition. Aquatic organisms such as fish, phytoplankton, and zooplankton are seriously stressed—in some cases eliminated—by the drastic changes in pH following lake liming. Lime may increase the pH, but it does not remove heavy metals leached from surrounding soils to the lake as a result of acid deposition. In fact, liming may actually increase the toxicity of heavy metals in the lake water. Liming is designed to temporarily reduce some of the effects of acid deposition but does not contribute to the solution of the problem. It treats some of the symptoms but not the disease.

From a purely economic standpoint, it is not a very attractive alternative. In Wisconsin, we have determined the cost of lake liming is a minimum of $165 per lake surface acre for accessible lakes. It is only practical to lime lakes less than 75–100 acres. If acidified lakes are inaccessible, liming costs escalate rapidly. Wisconsin has almost 1 million acres of lake surface area. If only 10 percent of these lakes were acidified, it would cost a minimum of $16.5 million to add lime. Liming may have to be repeated in many lakes due to continued acid deposition or depletion of buffering capacity in the watersheds. No practical methods exist for liming nonagricultural watersheds.

In most cases we do not have concrete dollar figures on the cost of acid deposition to the economy of northern Wisconsin. We do know that it could have significant effects on a number of very high budget items in our State economy.

Senator MITCHELL. Mr. Martini, may I interrupt and ask if we could move on in order to let some of the other participants say a few words? Then at the conclusion perhaps there will be some questions and a chance for interchange, so everybody would have a chance to say something.

I would like to ask Dr. Norton to summarize his statement. We do have a written statement, Dr. Norton, which will be placed in the record. Then I would ask Mr. Heffern and Ms. Gass also to summarize.

Dr. Norton, I noticed in reading through your statement quickly that you addressed the question of the effect of acid rain on forest products. I would like to ask you to discuss the state of knowledge in that area. There appears to be considerable uncertainty about that. I wonder if you might discuss orally your thoughts in that area, Maine being, of course, a State heavily dependent on forest products.

STATEMENT OF DR. STEPHEN A. NORTON, PROFESSOR O
GEOLOGICAL SCIENCES AND CHAIRMAN OF THE DEPART
MENT OF GEOLOGICAL SCIENCES, UNIVERSITY OF MAINE A
ORONO

Dr. NORTON. I will discuss that in the context of my other com
ments.

I am a geochemist by training and have been researching in th
general area of the interaction of water and rocks in soils. For th
past 6 years I have been involved in acidic precipitation researc
which has been funded by the National Science Foundation, th
Environmental Protection Agency, the Department of the Interio
the Department of Agriculture, and the Governments of Norwa
and Sweden.

I have been researching in four general areas and will commen
briefly on them to try to demonstrate not specifics about economi
impact but the breadth of impact as I see it. We are really in th
midst of a long-term experiment in putting acidic rain on terrestr
al and aquatic ecosystems. All the answers are not in. We do kno
where we are going to end up 5, 10, or 20 years from now. It is
rather interesting and potentially dangerous experiment.

I have been charged by the Environmental Protection Agency t
analyze the entire United States to identify the distribution o
sensitive areas, areas where aquatic ecosystems would be vulne
able to acidic precipitation by virtue of the underlying geology. M
Martini has addressed some of these problems.

Based on this study, I can say that as much as 98 percent of th
area of some States—Rhode Island and New Hampshire are goo
examples—is underlain by sensitive areas where we would expec
to see significant impacts on the freshwater aquatic ecosystem

Where historic data on the water quality are present the vas
majority of lakes and streams, approximately 90 percent in thes
sensitive areas, show a decline in pH and alkalinity in the past 1
or 20 years.

Where our maps indicate sensitivity of aquatic ecosystems w
have field checked in three States and tested our thinking. Low pH
and low alkalinity in waters are present. In other words, we ar
now able to predict, first of all, where sensitive waters will occu
and, second, predict where we would expect to find tempora
changes in water quality.

The implications of this, in view of baseline data in much of th
Eastern United States, are that there are many, many unmeasure
lakes and streams which have already suffered a decline in pH an
alkalinity with the associated impact on fisheries and other aquati
flora and fauna.

Our analysis shows that 43 percent of the United States east o
the Mississippi River is underlain by sensitive areas. Land use an
other mitigating circumstances reduce this figure somewhat bu
nonetheless, we can say rather categorically that as the pH of rai
and snow decreases and the area affected by this acidic precipita
tion increases the impact will grow and a large number of lake
and streams will be affected, and the fisheries contained in ther
will be affected.

In summary, with respect to that component of my research
historical data, limited as it is, are available for some lakes an

indicate that in sensitive areas lakes and streams are becoming more acidic.

Extrapolating to areas where we do not have baseline data, at least historically, we can imply that in fact the damage is very widespread and increasing.

The second aspect of my research deals with the analysis of cores of sediment taken from lakes in the northeastern part of this country. They indicate some rather startling conclusions.

The news media would have us believe, not intentionally, that the problem of acidic precipitation and its associated impact is a recent phenomenon. There is evidence in the lakes and peat bogs of the eastern part of the United States that acidic precipitation started at least 100 years ago, and it has been spreading in both regional extent and severity since that time. It is only in the past 10 or 15 years that our attention has been aroused by the reporting of loss of fisheries in the Adirondacks and other places.

There is a biological lag; in other words, as acidic precipitation develops chemical effects in lakes and in streams, the biology lags in its response but, nonetheless, it does follow in those lakes which are located in sensitive terrains.

The third area of my research is the area that Senator Mitchell has asked me to address. That is the impact on forests. Maine's largest industry is forestry. It is important in Wisconsin, and in many States in the Eastern United States it is the backbone of the economy.

A graduate student of mine has just completed a study of the chemistry of forest floor litter—that is, the organic layer in the bottom of the forest—from southern Vermont to the Gaspé Peninsula, Quebec. He has controlled as many variables as possible with respect to altitude, vegetation, and so on. It is a reasonably tight scientific study.

This transect is located along a very strong precipitation pH gradient. In southern Vermont the rain and snow is very acidic with an average pH approaching 4 and at the Gaspé Peninsula, the pH is averaging around 4.6.

The conclusions of that study are that, as precipitation becomes more acidic, calcium, magnesium, and potassium—three very important nutrients—are preferentially leached from the soil and leaching, in general, is accelerated in the soils. In other words, the soils in southern Vermont are now nutritionally impoverished relative to equivalent soils in the Gaspé Peninsula.

Associated with this acidic precipitation and its leaching of the forest soils is an atmospheric loading of heavy metals, including lead and zinc. Lead has been demonstrated to be accumulating to a rather large extent in these forest soils. Zinc is also accumulating in our forest soils in the East, but where the acidic rain is sufficiently acid zinc is now being leached from the forest soils and, of course then is present in larger amounts in ground water and in surface waters—lakes and streams.

The short-term implications of this are rather straightforward. As we leach nutrients from the forest soils, that means there are more nutrients in ground water, lakes, and streams. Therefore, one might expect an increased productivity of terrestrial ecosystems

and aquatic ecosystems while these nutrient levels are kept high by the accelerated leaching.

However, we are drawing money out of the bank in a sense. There may come a time—and we do not know if and when this time is coming—when the reservoir of nutrients in the soils will be sufficiently depleted so that productivity of the forest ecosystems would be diminished. This is the long-term experiment I talked about earlier in my remarks..

It seems to have happened in Western Europe. The implications are it may be happening in Sweden, although I do question the results reported from time to time in the newspapers about decreased forest productivity in Sweden.

There have been some studies in Norway which have indicated an increased productivity in forest ecosystems. This is attributed to the fertilizing effect of the extra nitrogen and sulfur in the acidic rain. This may be just a short-term effect. We should be looking a little further down the road.

Senator BOSCHWITZ. Pardon me, Dr. Norton. Would you tell me what a terrestrial ecosystem is?

Dr. NORTON. This would be anything above the water line, so to speak. It would not include the rivers. It would not include the lakes. It would include the forests and agricultural land, about which other people have things to say.

I was going to mention something about ground water, but Mr. Martini's comments are, in my opinion, correct and sufficiently adequate to cover the situation in Maine.

We have acidic rain in Maine, as does all of the Northeast. The implications are that because ground water really is nothing more than precipitation which is under the ground, if we change the chemistry of rain and snow we will change the chemistry of ground water, and in some areas, in particular southwestern Sweden, it has already caused human health effects.

Senator MITCHELL. Thank you very much, Dr. Norton.

[The prepared statement of Dr. Norton follows:]

Written testimony presented to the Committee on the Environment and Public Works
Washington, D.C. 9/23/80

I am Dr. Stephen A. Norton, Professor of Geological Sciences and Chairman of the Department of Geological Sciences at the University of Maine at Orono. I am part of a research team which has been assembled at the University to study the impact of acidic precipitation on terrestrial and aquatic ecosystems in Maine, in New England, in Scandinavia, and elsewhere. Our research is sponsored by the U.S. National Science Foundation, U.S. Department of the Interior, U.S. Environmental Protection Agency and U.S. Department of Agriculture. I am presently doing research in four areas. First, I am attempting to identify sensitive areas in the conterminous United States, areas where impact from acidic precipitation is expected. Second, we (I and Professor Ronald B. Davis) are studying temporal changes in surface water chemistry in both lakes and streams. Third, we (Davis and I) are analyzing the historic record in sediment cores from lakes and peat bogs to study the fossil record of acidification and changes in metal fluxes in aquatic ecosystems. Fourth, I and Denis Hanson, a graduate student, are studying chemical changes in soils. These changes include leaching of such nutrients as calcium, magnesium, potassium, and manganese and the accumulation or loss of metals such as lead, iron, zinc, cadmium, manganese, and aluminum.

I. The first area of research, the identification of sensitive areas (Hendrey et al., 1980), has been based on an analysis of the bedrock geology of the U.S. We have directed our studies towards an understanding of the capability of the underlying rocks to chemically neutralize acidic precipitation. The underlying rocks indirectly control the capability of the soil to neutralize acid as well, in as much as the soils are generally derived from the underlying rocks. The rocks of the U.S. have been simplistically divided into four different catagories according to their capability to neutralize acidic precipitation. Based on

this classification of rocks we have identified areas where we expect to find an impact from acidic precipitation. Areas have been classified as type 1 (impact expected), 2 (impact probable), 3 (impact unlikely), and 4 (impact not expected). In the states of Virginia, North Carolina, and New Hampshire, maps generated on these bases were able to predict waters of low alkalinity and low pH or high acidity. Waters of low alkalinity (low resistance to changes in pH) and intermediate pH are susceptible to being acidified if the precipitation is acidic.

II. Studies of these sensitive areas (1 and 2) should reveal any temporal chemical changes in surface waters which may be occurring due to acidic precipitation.

Based on our maps we predicted that certain areas of these three states would have not only low alkalinity and low pH waters but also would have waters which have had the pH and alkalinity lowered over a period of years due to the increasingly acidic precipitation. Waters from North Carolina and New Hampshire had earlier pH and/or alkalinity measurements against which we could compare modern measurements. The time distribution of measurements ranged from intervals of a few years to a few tens of years. The vast majority of these waters, both lakes and streams, showed a decrease in pH or alkalinity or both suggesting: 1) our sensitivity analyses are useful in identifying sensitive areas and 2) acidification of surface waters, including lakes and streams, is occurring. In New England the following percentages of areas of states are sensitive (rock types 1 and 2): New Hampshire (98), Vermont (54), Maine (72), Massachusetts (63), Connecticut (93), and Rhode Island (98). Data for other states east of the Mississippi are included in a table enclosed with this report. For the U.S. east of the Mississippi River, 43 percent of the area is sensitive, where impact is expected or is probable.

Studies are presently under way to determine the distribution and percentage of sensitive areas for states from the western half of the United States. Many areas

Land Area Susceptibility

	Percentage of Rock Type #1	Percentage of Rock Type #2	Total percentage of Rock Types #1 & 2
Alabama	0.54	51.36	51.90
Connecticut	8	85	93
Delaware	0.00	18.60	18.60
Florida	0.00	5.82	5.82
Georgia	6.11	68.21	74.32
Illinois	0.00	3.58	3.58
Indiana	0.00	13.25	13.25
Kentucky	0.00	38.50	38.50
Louisiana	0	0	0
Maine	17	55	72
Maryland	21	76	97
Massachusetts	32	31	63
Michigan	6.48	8.52	15.00
Minnesota	6.74	58.04	64.78
Mississippi	0.00	71.13	71.13
New Hampshire	30	68	98
New Jersey	10	80	90
New York	6	65	71
North Carolina	10.40	47.59	57.99
Ohio	0	0.51	0.51
Pennsylvania	1	47	48
Rhode Island	63	35	98
South Carolina	9.37	16.66	26.03
Tennessee	0.50	18.32	18.82
Vermont	3	51	54
Virginia	7	55	62
West Virginia	0	39	39
Wisconsin	0.00	63.89	63.89
All states	4.32	38.68	43.00

See text for explanation for rock type 1 and 2

outside the often cited Adirondack Mountains of New York are sensitive.

Studies of temporal changes of the quality of surface waters due to acidic precipitation rely on base line data gathered ten, twenty, or more years ago for comparison. Various problems of measurement and intercomparison exist but generally errors are randomly distributed in the data. Therefore, large data bases are significant if they do show trends in acidity of surface waters. The emphasis by researchers has been on the lake waters of the northeast and the Boundary Waters Canoe Area of the upper midwest. Without getting into specifics all the data for sensitive lakes and sensitive regions suggest a decline in pH (increasing acidity) and alkalinity, sometimes leading to economically recognizable effects such as the loss of the fishes. These changes have taken place over times ranging on the order of a few years to a few tens of years.

However, south of the limit of glaciation for North America, including much of Pennsylvania and to the south along the Appalachian Mountains, lakes are rare. Impact from acidic precipitation to aquatic ecosystems is limited to ground water (which has been completely ignored in this country) and small streams. Comparative studies indicate that the latter are impacted significantly by acidic precipitation (Hendrey et al., 1980) and one can expect the impact on fisheries in streams to be pronounced in sensitive areas. Considering the percentage of sensitive areas in the eastern United States (see the enclosed table) the impact on fisheries may be and probably is very large and widespread although not commonly recognized. All areas identified as sensitive to impact from acidic precipitation have been shown by field measurements to have suffered an impact such as decreasing pH and alkalinity when previous data were available for comparison.

III. Professor Ronald B. Davis from the Department of Botany and Quaternary Studies at the University of Maine at Orono and I are involved in research which constructing the onset and development of acidic precipitation in the northeastern United States, Sweden, and Norway. Our research has focused on the record

left in the sediments of lakes. We are attempting to determine how lake/drainage basis complexes respond chemically and biologically to increasing atmospheric loading of acid and certain metals, for example lead and zinc, from precipitation.

We have determined that in the northeastern United States chemical effects of polluted precipitation can be noted as early as 1880 to 1900, continuing and increasing in severity up to the present (Norton et al., 1980). Biological effects, especially changes in the flora, become evident in some lakes as long ago as the 1940's. Although our awareness of acidic precipitation spans only the last 6 to 8 years in this country, it has been here and its effects have been increasing for approximately 100 years. Only the demise of fishes in about 200 lakes in the Adirondack Mountains of New York has alerted us to the potential and actual impact on natural ecosystems. Our studies indicate vastly altered levels of metals (for example, zinc, manganese and aluminum) in aquatic ecosystems (Norton et al., in press). The effects of these metals are generally negative on biological systems. For example, elevated levels of aluminum have been linked (perhaps in concert with decreased pH due to acidification) to loss of fish populations. Economic impact of changing surface water chemistry is poorly known because much of the impact is occurring in streams and rivers where modern data on fisheries are poor and pre-pollution base line data are absent.

IV. In 1975 I wrote a somewhat theoretical paper speculating that, among other things, aluminum should be mobilized from soils and found in higher concentrations in surface waters and ground waters due to acidic precipitation. Subsequently, aluminum has been implicated in the demise of fishes in many lakes and probably also in streams; in a study in Sweden it has been shown to be a significant factor in human health. Similar lines of thinking suggest that soils should suffer the loss of certain metals due to the increasing acidity of precipitation. Studies from Sweden and West Germany suggest that this is

happening in those places. One of my graduate students, Denis Hanson, has determined that in eastern North America calcium, potassium, magnesium, and manganese are being preferentially leached from soils in those areas receiving acidic precipitation; the more acidic precipitation leaches more of these elements. Zinc is leached or accumulates depending upon the result of the interplay of increased atmospheric deposition of acid and zinc. Lead is accumulating strongly in the soils. Similar results for lead and zinc were determined in a unique temporal study of soils from central Massachusetts (Siccama et al., 1980). The short term implication of these studies on high elevation spruce forest organic soils is a short term increase of many nutrients in both soil waters and surface waters. This should (may?) be followed by a decrease in nutrient availability as the nutrient reservoir in the soils is drawn down due to the increasing acidity of precipitation and the accompanying accelerated leaching. The implication of this scenario is a decreased productivity of forest ecosystems over the long term. This has not been demonstrated for the following possible reasons: 1) the depletion of nutrients is not and will not be sufficient to cause measurable effects, 2) the addition of the nutrients nitrate and sulfate from atmospheric deposition may offset the loss of other nutrients, 3) the depletion process has not gone on long enough for measurable impact. Europe intensively manages its fiber production. A 5 to 10 percent decrease in productivity there due to soil nutrient impoverishment could not be tolerated. The United States presently produces more fiber than it uses but within 5 to 10 years this will probably not be true and a decrease in productivity would be economically very significant. I suggest here that the impact on forest soil nutrient reservoirs due to acidic precipitation has the greatest potential for economic impact, next to damage to anthropogenic structures.

References Cited

Hendrey, G.R., Galloway, J.N., Norton, S.A., Schofield, C.L., Shaffer, P.W., and Burns, D.A., 1980, Geological and hydrochemical sensitivity of the eastern United States to acid precipitation: U.S. E.P.A. - 600/3-80-024, 100 p.

Norton, S.A., Hess, C.T., and Davis, R.B., 1980, Rates of accumulation of heavy metals in pre- and post-European sediments in New England in Eisenreich, S.J. (ed.), Input of Atmospheric Pollutants to Natural Waters: Ann Arbor Science.

Norton, S.A., Williams, J.S., Hanson, D.W., and Galloway, J.N., in press, Changing pH and metal levels in streams and lakes in the eastern United States caused by acidic precipitation: U.S. E.P.A.

Siccama, T.G., Smith, W.H., and Mader, D.L., 1980, Changes in lead, zinc, copper, dry weight, and organic matter content of the forest floor of white pine stands in central Massachusetts over 16 years: Envir. Sci. Tech., 14, p. 54-56.

Senator MITCHELL. Mr. Heffern?

STATEMENT OF JAY M. HEFFERN, ASSISTANT EXECUTIVE DIRECTOR, MINNESOTA POLLUTION CONTROL AGENCY

Mr. HEFFERN. Thank you, Mr. Chairman.

As you indicated, I have filed a statement with the committee. Therefore, I will be brief.

Senator MITCHELL. Without objection, that prepared statement will be made part of the hearing record.

Mr. HEFFERN. Minnesota perhaps is not as far along in its understanding of its problem as Wisconsin or perhaps other States in the country. Consequently, I cannot state with any certainty how severe the problem is, but the data certainly suggests that there is a serious problem.

Given that uncertainty, the economic numbers that we have developed are admittedly crude. At best, they represent some guesswork as to what the implications might be on Minnesota's economy if there is the acid rain problem that we think.

Let me focus on a few elements of the economy—first, agriculture.

Agriculture and agribusiness employ about one-third of the State's workforce and contribute $20 billion annually to the economy. Almost 57 percent of the land in Minnesota, about 30 million acres, is devoted to agriculture.

At this time there is no evidence that the acid rain problem is impacting productivity. However, the long-term concern may be lost soil fertility. If this occurs and if it results in a decline of only 2 to 3 percent, this could mean a cost to the State of Minnesota of $400 to $600 million a year.

The second major element in Minnesota's economy is the forest products industry, about 44 percent or 18 million acres of the State's forest. The pulp and paper industry and the forest products industry contribute about $1.3 billion annually to the State's economy.

Dr. Norton has indicated that there is some research, some perhaps questionable research, that talks about a decrease in forest

productivity. Some of the literature suggests a range anywhere from zero to 15 percent.

Using a 5-percent estimate in decrease of productivity, which may or may not be correct, the State's annual loss from forest products could approximate $65 million a year.

Finally, Minnesota, like Wisconsin, has a heavy tourist industry. Tourists spend approximately $1.3 billion a year in Minnesota. Minnesota itself has 1.8 million licensed fishermen who spend an estimated $500 million annually in Minnesota. Mr. Martini has outlined the relationship between fishing, tourism, and the acid precipitation problem. In terms of dollars to Minnesota, that may approximate an annual loss of $78 million.

In addition, there are some national studies that talk about the cost on human health and corrosion on man-made materials. In my statement we extrapolated some figures from Minnesota based on population from those national studies. Those figures suggest an annual cost to Minnesota of $26 million in human health and $40 million a year corrosion on man-made materials, based on extrapolation.

At this point, Mr. Chairman, I will stop. As I say, I have submitted a statement for the record. If you or Senator Boschwitz have any questions, I will try to answer them.

Senator MITCHELL. Thank you, Mr. Heffern.

[The prepared statement of Mr. Heffern follows:]

STATEMENT BY
JAY M. HEFFERN
ASSISTANT EXECUTIVE DIRECTOR
MINNESOTA POLLUTION CONTROL AGENCY
BEFORE THE JOINT HEARING
SMALL BUSINESS COMMITTEE
AND
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE

SEPTEMBER 23, 1980

Mr. Chairman, Members of the Joint Committee, my name is Jay Heffern. I am Assistant Executive Director of the Minnesota Pollution Control Agency. For those of you not familiar with that Agency, it is the state equivalent of the Environmental Protection Agency and is responsible for protecting Minnesota's water, air, and land resources from all forms of pollution.

I welcome the opportunity to appear before you this morning to discuss acid rain - a problem that is facing not only Minnesota but the entire Nation. You have already heard a discussion of the acid rain phenomena. Consequently, my remarks will be limited to the implications of acid rain on the State of Minnesota.

My statement will focus on three issues: First, the state's susceptibility to acid rain; second, a rough estimate of the economic losses which may be experienced in Minnesota if the impacts from acid rain continue; and finally a description of the State's response to this problem.

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Susceptibility of Minnesota to Acid Rain

Within the last one million years, four glaciers advanced and then retreated over the area which is now Minnesota. As a result, the State was left with rich farmland, vast forests, and over 15,000 lakes. These glaciers scoured the land exposing bedrock. Consequently, a major portion of northeastern Minnesota is covered by thin soils and outcroppings of granite bedrock. The lakes in this area are mostly soft water lakes. The thin soils and soft water lakes have only limited ability to neutralize acidity. Therefore, this area of the State is highly sensitive to acid rain. In addition, this part of the State contains the largest collection of peat lands and welands in the 48 contiguous states. These resources also are potentially susceptible to the impacts from acid rain. Finally, the State has millions of acres of prime agricultural land in western and southern Minnesota. Although these prairie soils have some neutralizing capacity, the State is concerned that the long-term effects of acid rain may impact the fertility of the land.

Unfortunately, there is not sufficient data available to state with certainty how severe the acid rain problem may be throughout Minnesota. The data that is available does suggest a serious problem. For example, recent studies show that northeastern Minnesota and the metropolitan twin city area are experiencing acidic rainfall with a pH as low as 3.6.

Comparing this data to limited data that was collected in 1970, suggests that the rain and snow in northeastern Minnesota is now up to 10 times more acidic than it was 10 years ago.

Further, seven stations for monitoring sulfur and precipitation chemistry have existed in Sherburne, Wright, and Sterns counties (central Minnesota), since 1976. Of 282 single samples of rainfall collected at seven different sampling locations during the period from May 15 to October 15 of 1976, 1977, and 1978, 86 percent were shown to have sulfates and nitrates in the form of a neutralized salt. Acidity (pH) in these samples ranged from 3.76 to 7.90. About 30 samples had a pH value less than 4.5.

Finally, lake surveys conducted by the Environmental Protection Agency and the Minnesota Pollution Control Agency show that from 60 to 80 percent of the lakes in northeastern Minnesota are susceptible to acid rain. State-wide, up to 20 percent of the State's 15,000 lakes may be susceptible. Several lakes currently have acid levels high enough to interfere with reproduction of some fish species. Due to the lack of historical data, the State does not know if these lakes are naturally acidic or have been impacted by acid rain.

This data has raised the obvious question: What is causing or contributing to these high levels of acidity? The State has a number of industries and utilities that emit SO_2 and NO_x -- the precursor of acid rain. Increased dependence on coal will certainly increase these emissions. However, because of upper air movement and meteorological storm patterns, areas outside of the State are suspected as major contributors. A recent Canadian study has estimated that for the Boundary Waters Canoe Area, about 22 percent of the acid deposition is due to Minnesota sources, 29 percent comes from Canadian sources, and about 49

PERCENT FROM AMERICAN SOURCES OUTSIDE OF MINNESOTA. THE TRANSPORT PHENOMENON WAS ALSO IDENTIFIED IN A STUDY OF PHOTCHEMICAL OXIDANTS (OZONE), COMPLETED FOR THE MINNESOTA POLLUTION CONTROL AGENCY BY PACIFIC ENVIRONMENTAL SERVICES IN EARLY 1979. THAT STUDY INDICATED THAT 61 TO 85 PERCENT OF THE OZONE POLLUTANT IN MINNESOTA ORGINATED IN EASTERN INDUSTRIAL CENTERS.

Economic Implications of Acid Rain on the State of Minnesota

THE STATE'S PRESENT UNDERSTANDING OF THE IMPLICATIONS OF ACID RAIN ON MINNESOTA'S ECONOMY IS LIMITED. TOO MANY UNKNOWNS ARE INVOLVED TO MAKE AN ACCURATE ASSESSMENT OF THE ECONOMIC IMPACTS. HOWEVER, SOME GENERAL OBSERVATIONS CAN BE MADE. FIRST, WITH RESPECT TO HUMAN HEALTH. NATIONAL FIGURES INDICATE THAT THE HUMAN HEALTH COST OF ACID RAIN MAY BE 1.5 BILLION DOLLARS ANNUALLY. AN EXTRAPOLATION OF THESE FIGURES FOR MINNESOTA RESULTS IN AN ANNUAL STATE COST OF ABOUT 26 MILLION DOLLARS A YEAR. SECOND, AGAIN THE NATIONAL FIGURES INDICATE THE ANNUAL COST OF CORROSION ON MAN-MADE MATERIALS TO BE IN THE RANGE OF 2 TO 3 BILLION DOLLARS. THIS SUGGESTS A 40 MILLION DOLLAR A YEAR COST TO THE STATE OF MINNESOTA. THIRD, THREE SEGMENTS OF MINNESOTA'S ECONOMY - AGRICULTURE, FORESTRY, AND TOURISM - MAY BE IMPACTED.

MINNESOTA IS ONE OF THE LEADING AGRICULTURAL STATES IN THE COUNTRY. AGRICULTURE EMPLOYS ONE-THIRD OF THE STATE'S WORK FORCE AND CONTRIBUTES 20 BILLION DOLLARS ANNUALLY TO THE ECONOMY. ALMOST 57 PERCENT OF THE LAND IN MINNESOTA IS DEVOTED TO AGRICULTURE. THIS REPRESENTS OVER 30 MILLION ACRES. AT THIS TIME, THERE IS NO EVIDENCE THAT PRODUCTIVITY IS BEING IMPACTED. HOWEVER, THE LONG-TERM AGRICULTURAL PROBLEM MAY BE LOSS OF SOIL FERTILITY.

IF THIS OCCURS AND RESULTS IN A DECLINE OF AGRICULTURAL PRODUCTIVITY OF ONLY 2 TO 3 PERCENT, IT WOULD MEAN A COST TO THE STATE OF 400 TO 600 MILLION DOLLARS A YEAR.

A SECOND MAJOR ELEMENT IN MINNESOTA'S ECONOMY IS THE FOREST PRODUCTS INDUSTRY. ABOUT 44 PERCENT OR 18 MILLION ACRES OF THE STATE IS FORESTED. THE PULP AND PAPER INDUSTRY AND THE FOREST PRODUCTS INDUSTRY CONTRIBUTE ABOUT 1.3 BILLION DOLLARS ANNUALLY TO THE STATE'S ECONOMY. ALTHOUGH ACID RAIN IS CURRENTLY FALLING IN FORESTED AREAS OF THE STATE, THE IMPCAT IS NOT CLEARLY KNOWN.

SOME RESEARCH HAS ESTIMATED A DECREASE IN FORST PRODUCTIVITY AS A RESULT OF ACID RAIN, RANGING ANYWHERE FROM 0 TO 15 PERCENT. USING A 5 PERCENT ESTIMATED DECREASE IN PRODUCTIVITY, THE STATE'S ANNUAL LOSS IN THE FOREST PRODUCTS AREA COULD APPROXIMATE 55 MILLION DOLLARS A YEAR.

FINALLY, THERE IS A SIGNIFICANT POTENTIAL COST TO MINNESOTA'S TOURISM INDUSTRY. TOURISTS SPEND APPROXIMATELY 1.3 BILLION DOLLARS A YEAR IN MINNEOSTA. IN ADDITION, MINNESOTA HAS 1.8 MILLION LICENSED FISHERMEN, WHO SPEND AN ESTIMATED 500 MILLION DOLLARS A YEAR ANNUALLY IN MINNESOTA. MUCH OF THIS FISHING ACTIVITY OCCURS IN THE NORTHERN PART OF THE STATE, WHICH IS SENSITIVE TO ACID RAIN. THE CURRENT DATA SUGGEST THAT 2300 OF THE STATE'S 15,000 LAKES ARE IN DANGER OF ACIDIFICATION. THE TOURISM AND FISHING ECONOMIES COULD SUFFER AN ANNUAL LOSS OF 78 MILLION DOLLARS. THESE ESTIMATES ARE ADMITTEDLY CRUDE AND MUST BE VIEWED AS SUCH. NONETHE LESS, THE POTENTIAL ECONOMIC LOSSES IN THE STATE DICTATE THAT IMMEDIATE ACTION MUST BE TAKEN TO DEAL WITH THE ACID RAIN PROBLEM.

State's Response to the Problem

The Minnesota Pollution Control Agency formed in January of last year a state acid rain task force. This task force was composed of representatives of various state agencies.

The charge of the task force was to formulate a strategy for Minnesota to attack the acid rain problem. It became apparent very soon after formation of this task force that additional funds were needed to begin addressing this problem.

The agency and the acid rain task force sought that funding from the Minnesota Legislature last session. The legislative response was the passage of the Acid Precipitation Act of 1980, which I have attached to my testimony for your information.

Essentially, that Act directs the Pollution Control Agency to identify the sources of the acid rain problem in Minnesota and to develop the appropriate scientific and technical expertise necessary to solve this problem. The Legislature appropriated $100,000 to support this effort. The initial focus of the State's effort is data collection and analysis. The State is collecting and analyzing existing air and water quality data, fish populations data, and drinking water supplies data to determine the nature and extent of the problem in Minnesota. Through this effort, additional data needs will be identified.

It is anticipated that this work will be completed by October 1 of next year. This should result in a better understanding of the acid rain problem in Minnesota and should be a contribution to the National program to solve this problem.

Mr. Chairman, that concludes my prepared statement. I will be happy to respond to any questions that you may have.

POLLUTION—ACID PRECIPITATION

CHAPTER 490

H.F.No.3855

An Act relating to pollution; recognizing the extent and severity of the problem of acid precipitation; appropriating funds and designating state agencies and departments to conduct activities designed to identify, control and abate acid precipitation.

Be it enacted by the Legislature of the State of Minnesota:

Section 1. Legislative findings; intent. The legislature recognizes that acid precipitation resulting from the conduct of commercial and industrial operations both within and without the state poses a present and severe danger to the delicate balance of ecological systems within the state, and that the failure to act promptly and decisively to mitigate or eliminate this danger will soon result in untold and irreparable damage to the forest, agriculture, water, fish and wildlife resources of the state. It is therefore the intent of the legislature in enacting this act to commit the financial and technological resources of the state toward cooperative programs involving the state, adjoining jurisdictions and the federal government, which programs shall be designed to recognize the nature and extent of the problems of acid precipitation, identify the sources thereof, and develop the appropriate scientific and technological expertise essential to solving the problems and maintaining the balance of ecological systems.

Sec. 2. Appropriations. The following sums are appropriated from the general fund to the agency and departments indicated for the purpose of conducting research and development projects, which may be in conjunction with appropriate authorities in the federal government, the state of Wisconsin and the province of Ontario, with the objective of identifying, controlling, and abating acid precipitation:

1. To the Minnesota pollution control agency—$332,383;
2. To the Minnesota department of natural resources—$34,287;
3. To the Minnesota department of health—$33,430.

The agency and departments are each authorized to increase their complement by one full-time position.

Funds appropriated by this section shall not lapse but shall remain available until expended.

The Minnesota pollution control agency is designated as the coordinating agency responsible for initiating contacts with other jurisdictions and coordinating research and development activities and projects. It is a condition of acceptance of the appropriations made by this section that each agency or department receiving an appropriation shall submit work programs and semiannual progress reports in a form determined by the legislative commission on Minnesota resources. None of the monies provided in this section may be expended unless the commission has approved the pertinent work program.

In addition, the agency shall consolidate and present to the legislature or appropriate interim committees thereof, recommendations for legislation deemed necessary to facilitate the control and abatement of acid precipitation.

Sec. 3.

116E.86 Public education on acid precipitation.

The Minnesota environmental education board shall conduct a program of public education on acid precipitation. The board shall report on the progress of the program to the respective chairmen of the house committee on environment and natural resources and the senate committee on agriculture and natural resources by January 15, 1981.

Sec. 4. This act is effective the day following final enactment.

Approved April 7, 1980.

Senator MITCHELL. Why don't we permit Ms. Gass to make a brief summary of her remarks and then we will proceed to questions?

STATEMENT OF BARBARA J. GASS, AIR QUALITY DIVISION, MICHIGAN DEPARTMENT OF NATURAL RESOURCES

Ms. GASS. I also have submitted a written statement to which I would refer you for additional detail.

Senator MITCHELL. Your prepared statement in its entirety will be made part of the hearing record.

Ms. GASS. Regarding the existence of damage due to acid rain in Michigan, such damage has not been recognizable in our State. However, that does not mean that we believe there has not been any damage or will not in the future be any damage. The reason I say this is that we have a lack of data concerning the damage that aquatic and terrestrial ecosystems have suffered in Michigan.

However, there are a few items of interest to the committee for which I can provide some information.

First, we know we have areas that are susceptible to acid deposition. Based on the geologic history of the upper Great Lakes region, the western end of Michigan's Upper Peninsula is particularly susceptible to damage due to the lack of compounds to neutralize acidic inputs. This is an area of numerous lakes and streams. Many of them that have been monitored do have a low buffering capacity.

Some of the other susceptible phenomena include fish species such as brook trout and certain tree species.

Because of the diverse effects of acid rain and the diversity found in Michigan, we have a strong potential for damage in the State. I want to emphasize that due to the amount of agriculture, commercial forestry, sports fishery, and use of Michigan's water resources, acid deposition could have a substantial effect on our economy.

Commercial forestry in Michigan is a $1.2 billion industry. This ranks among the top five States in the Nation in this respect.

Agriculture is Michigan's second largest industry with an annual income of approximately $2.4 billion and an economic impact of $8 billion annually including processing.

We don't have any figures at this time on the total tourism industry, but with respect to the fisheries end of that industry the State has approximately 11,000 inland lakes of which 2,000 have a size greater than 50 acres. In 1978 the inland fisheries alone, not including the Great Lake fisheries, had a total economic impact of $250 million to the State.

Second, we know we are receiving acid deposition. Measurements taken in the early 1970's in Michigan indicate that the entire State receives acid rain, with the most acidic precipitation falling in the lower peninsula. Recent measurements at three sites indicate that annual average values are around a pH of 4.5.

Third, we know we need to collect additional data, including types of data and locations where we have never collected it before. Although we have an extensive monitoring program in the State, the objectives of those efforts have been somewhat different than efforts to examine the acid rain problem. Consequently, strategies

of this program, including which areas to investigate, have not included areas suspected of acid rain sensitivity.

Although we recognize we have areas sensitive, that we are receiving acid deposition and we need to collect additional data, State funds to investigate the problems currently do not exist. Michigan is currently experiencing severe budget problems which not only do not allow for expansion of environmental programs, but have required cutbacks to the tune of $1.2 million in current environmental programs. The State is currently facing a budget deficit which may require another round of cuts in environmental programs.

We urge that the Federal Government, when it is allocating funds that have been committed to acid rain research, consider the requirements that will be made of the State in monitoring, assess historical data and other efforts.

In summary, we are concerned about our resources and recognize that much work remains to investigate the problem in Michigan. We are also concerned because there are no State funds available to investigate these areas.

Senator MITCHELL. Thank you very much, Ms. Gass.

[The prepared statement of Ms. Gass follows:]

STATEMENT OF

BARBARA J. GASS

STATE OF MICHIGAN

BEFORE THE

COMMITTEE ON SMALL BUSINESS

AND THE

COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS

UNITED STATES SENATE

SEPTEMBER 23, 1980

The State of Michigan appreciates this opportunity to present our concerns on the issue of acid deposition to this committee. My name is Barbara Gass and I am with the Michigan Department of Natural Resources in the Air Quality Division. I realize that my time is limited, but I would like to touch upon two aspects of the acid rain problem: existence of damage due to acid rain in Michigan and the potential for damage, and secondly, what action we believe is appropriate to combat the problem.

We have not seen recognizable damage in Michigan due to acid rain. However, that does not mean that we believe there has been or will be no damage. The reason I say this is that we have a lack of data concerning the damage that aquatic and terrestrial ecosystems have suffered in the state and the potential damage that could occur. There are, however, some areas of interest to this committee for which I can provide some information concerning Michigan.

First of all, we know that we have areas susceptible to acid deposition. Based on the geologic history of the upper Great Lakes region, the western end of Michigan's Upper Peninsula is particularly susceptible to damage from acid deposition due to the lack of compounds to neutralize acid inputs. This is an area of numerous lakes and streams, many of them of low buffering capacity. Certain types of brook trout have been found to be strongly affected by acid rain. These trout are found in many lakes and streams in Michigan, particularly in the Upper Peninsula. Since Michigan, due to its geographic location, receives considerable snowfall each year, our potential for sudden damage to aquatic life due to spring runoff of accumulated acidic inputs is increased. In many areas in the state, agricultural production uses irrigation water from public water supplies and

wells which could have increased metals content due to their acidity. Irrigation has increased 20% in the last year alone. Preliminary studies have indicated that conifers are the tree species most susceptible to acid rain. A significant portion of our forest coverage is of this type. As you can see, our resources, because of the diversity found in Michigan and the diverse effects of acid rain, could be subject to a wide spectrum of potential damage in our state.

I want to emphasize that due to the amount of agriculture, commercial forestry, sports fishery and use of Michigan's water resources that occurs in the state, acid deposition impacts could have a substantial effect on our economy. Commercial forestry in Michigan is a $1.2 billion industry. This ranks among the top five states in the nation in this respect. Use of pine pulpwood and sawlogs from Michigan support an important part of northern Michigan's economy. If, as hypothesized, Michigan's pine forests are its most vulnerable, growth reduction would result in considerable loss in forest revenues. Agriculture is Michigan's second largest industry, representing $2.4 billion annually in income and more than 8 billion including processing. One of the crops found to be most susceptible to air pollution damage is dry edible beans. Our state is first in the nation in production of these beans. Over 40% of the area within Michigan's political boundaries is freshwater. The state has approximately 11,000 inland lakes, of which 2000 have an area greater than 50 acres. Inland fisheries alone had a total economic impact of $250 million in 1978. The revenues from the fishing industry in Michigan rank highest of all the Great Lake states and among the top in the nation.

The State of Michigan places considerable importance on protection of our environment. For example, the Department of Natural Resources has recently been involved in such diverse environmental issues as the protection of wetlands in the state, a controversy over Indian fishing rights in Michigan's waters and a court suit against a chemical company resulting in orders that the company clean up a large toxic waste disposal problem.

Secondly, we know that we are receiving atmospheric acid deposition. Measurements taken in the early 1970s in Michigan indicate the entire state receives acid rain, with the most acidic precipitation falling in the Lower Peninsula. Recent measurements at three sites in Michigan indicate annual average values around a pH of 4.5. Average pH values range from 3.9 to 4.9 on Isle Royale in Lake Superior. These values are comparable to those currently being measured in Wisconsin and are slightly less acidic than measurements being made in the northeast part of the country.

Third, we know that we need to collect additional data including types and locations where we have never collected data before. This includes monitoring of precipitation and dry deposition acidity, taking pH and alkalinity measurements in small lakes and streams, monitoring the diversity of aquatic species (including initial stress indicates such as microcrustacea), increasing existing measurement frequency and concentrating efforts in certain areas of the state, and evaluating changes in forest and agricultural productivity. Although the Michigan Department of Natural Resources has an extensive monitoring program established to protect the state against environmental impacts, the objectives of those efforts have been somewhat different than studies to discover the extent

of the acid rain problem in the state. Consequently, strategies for these programs, including which areas to investigate, have not included areas suspected of acid rain sensitivity. For example, small seepage type lakes and first order waterways need to be examined as these are particularly susceptible. However, monitoring efforts have concentrated on lakes greater than 50 acres and major rivers. In order to accommodate the need for data specific to the acid deposition problem and maintain efforts to accomplish other important goals, monitoring efforts need to be expanded.

Although the state recognizes that we have areas susceptible to acid deposition, that we are receiving acid deposition, and that we need to collect additional information, state funds to investigate these areas further are simply not available. Michigan is currently experiencing severe budget problems, which not only do not allow for expansion of environmental programs, but have required cutbacks in current program areas of more than $1.2 million dollars. The state is now facing a multi-million dollar deficit, which may require yet another round of cuts from environmental programs. The governor's fiscal 1981 budget (which has received no legislative action as of this date) calls for a statewide reduction of $760 million in revenues and elimination of 3000 jobs from 1980 levels.

In light of the budget cutbacks that have been occurring, environmental administrators in the state have already critically examined the need for existing programs and assessed priorities. From that review has come a reaffirmation of the importance of maintaining concerted efforts in areas such as strong investigation and enforcement actions regarding improper toxic waste disposal. As a result, state funds do not exist to expand into the vital data gathering areas necessary to fully assess acid deposition problems in Michigan.

With respect to states' efforts to investigate acid deposition impacts, we see little effort on the part of the federal government to use any data available through the state governments or to coordinate their efforts with the states. We have seen little concrete initiatives result from such well-publicized efforts as the EPA policy conference held in Washington last spring. We have seen only one attempt by the Environmental Protection Agency to offer funding assistance in order to assess any aspect of the acid deposition problem in Michigan.

In comparing the Canadian province of Ontario's efforts in researching acid deposition with those of Michigan, it is almost embarrassing. Ontario's funding for acid precipitation studies in fiscal 1981 will amount to almost $5 million while Michigan's efforts are limited to the parttime efforts of task force researchers and some participation in a limited deposition monitoring program.

The lack of funding being appropriated to the states is exemplified by this EPA Region V monitoring program currently being set up. This includes 19 acid deposition stations within Michigan. Our responsibility is to set up and manage these 19 stations (originally scheduled to be operational by October 1 of this year). For this we have received very limited federal support for personnel and even this is of uncertain duration. It is our belief that due to this the resulting study will be either a poor quality effort or that the EPA regional office has an expectation of state funding contributions to make up for the federal lack of funding. Such an expectation will result in disappointment because funding cannot be supplemented by state revenues. Therefore, we urge that when the federal government is allocating the funds that have been committed to acid deposition research they are aware of the efforts that will be required of state agencies for monitoring, assessment of historical data, and other efforts. It is our hope that this realization will lead administrators to allocate a portion of the funds to the state agencies, particularly in the Midwest.

Finally, I wish to bring to the committee's attention our views concerning control action to be taken in the interim while the extensive research necessary is going on throughout the United States and Canada. It is our belief that although the acid deposition problem is not well defined, enough is known about the potential and actual effects of the phenomenon that interim control measures should be taken while additional data is gathered. It is anticipated that a variety of control options would be most effective in accomplishing this goal rather than across-the-board requirements of a particular type of control. We wish to stress that Michigan believes that initiatives to require these control actions must be taken at the national level rather than depending upon states to resolve this among themselves. We suggest this for two reasons: first, due to the scope of the problem, a single state's efforts to control their own emissions may not have a large effect on a distant region's acid deposition problem. Secondly, currently controversy among the states concerning the acid rain problem indicates that each state perceives the severity of the deposition problem slightly differently in terms of how it fits in with other state priorities, such as providing jobs for coal miners and low cost energy to its citizens. For these reasons, we strongly believe that a national policy emanating from the Environmental Protection Agency concerning existing precursor sources of the acid deposition problem is necessary.

Equally important is the need to consider the past history of emissions control in each state before any across-the-board regulation is implemented. This has resulted from the existing state implementation plan process and individual plant exemptions from those limits that have been allowed by the Environmental Protection Agency. We urge the Environmental Protection Agency to examine the

quickest and most cost effective method to produce substantial reduction in sulfur and nitrogen emissions and recognize the geographic areas where easily accomplished controls will have the most effect. For instance, implementation of coal washing regulations nationwide would produce little real benefit in terms of reductions in emissions in the State of Michigan with a resulting large increase in energy cost for its citizens. This is due to the fact that coal washing is only effective on higher sulfur coals (those over approximately 3% sulfur content) of which less than ten plants in the entire State of Michigan are using. There should be a recognition of the past control efforts of the individual state agencies. For example, we in Michigan are proud of the significant reductions in sulfur dioxide emissions that have been made in the past decade and believe our state-wide limitations properly reflect our citizens' concern for the environment and the need to consider costs. A state with a good record of past emission control action should not be penalized by a regulation requiring the same amount of emission reduction for that state as for a state which has allowed considerably more sulfur and nitrogen emissions. The approach of a limit based on state totals of emissions per amount of electricity generated may be an alternative.

Finally, we wish to mention that it is our observation that the general populace will become even more involved in this issue than they are presently. We believe the interest of the public will increase and the considerable news coverage that this issue has received is just a beginning. Thus, initiatives to lessen the menace due to this problem and distribute funds to investigate it should begin as soon as possible.

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In summary, the main concerns of Michigan are as follows:

1. We are concerned about our resources and recognize that much work is yet to be done in Michigan to define the impacts of the acid rain problem.

2. Funds are not available through state sources to investigate these concerns and we have seen little initiative on the part of the federal government towards assisting the states in this regard.

3. We believe that definitive control action should be taken as soon as possible, rather than waiting until all studies have been completed and absolute answers are at hand.

4. In taking such action, the federal government should recognize the inequity in amounts of emissions that occur from state to state.

Again, I thank you for this opportunity. I hope this discussion has provided some insights for the committee.

Senator MITCHELL. Let me ask just a couple questions. Th perhaps Senator Boschwitz and Senator Stafford may have so questions to ask.

Dr. Norton, you have indicated that you and others at the U versity of Maine have done research on acid rain in lakes in Mai and other places. Do you have an opinion as to whether or these effects are reversible and, if so, do you have any basis predicting the rate at which the lakes are becoming acidified a therefore how long a time period there may be within which can attempt to reverse it?

In other words, does it become irreversible at some point? If have we reached that point? If not, how long a period of time u we reach that point, if you can give us any estimate?

Dr. NORTON. The question is complex and the answer will ho fully be simple. It is possible almost immediately to reverse the problem in lakes with a straightforward liming of the lakes liming of the draining basin. These are techniques that are pr ently being employed on an experimental basis by the Swedish a Norwegian Governments, the Canadian Government, and the St of New York, as far as I know.

We do not restore the lakes to their original condition in respects, but we can restore the pH to reasonable levels and re tablish fish, and other changes become reasonably reversible.

I assume that your question is poking at what happens if turn off the atmospheric effluents and the pH of rain is allowed rise up to more reasonable levels. Soils take a long time to devel tens of years at least, probably hundreds of years to develop fai mature profiles. If they are chemically disturbed, it may take t

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or hundreds of years to restore these profiles to their original pre-pollution chemistry so that they act in a normal manner and the water that goes through them acts in a normal manner.

Therefore, I would say if left to themselves, the lakes, most of them, would return to their natural state within a time frame of perhaps 10 to 100 years.

Senator MITCHELL. What if, rather than controlling the emissions, those emissions increase as a result of our national policy to encourage the use of coal and discourage the use of oil?

Dr. NORTON. The impact, obviously, would grow but it grows rather unevenly because the sensitivity is geographically strongly controlled. For example, if I may cite Maine, we have studied rather intensively about 100 lakes in Maine but they were specifically chosen because they lie on sensitive grounds.

Of these 100 lakes, about 75 percent of them show a measurable decline in pH and alkalinity. Thus, we can say they are being impacted in some way or another. However, the vast majority of lakes in Maine, although they have had acid poured into them from the sky for a 100 years now, are probably not sensibly changed.

On the other hand, if we go to a terrain like the Adirondacks where a vast majority of the terrain is very sensitive, one is going to see many lakes rather rapidly tipping over the edge, so to speak, and losing their fisheries or going through biological changes that are not very desirable.

Senator MITCHELL. I note for the interest of the other Senators that on the table of page 3 of your statement Maine, Minnesota, and Vermont, the three States represented by Senators here, have a susceptibility substantially above the national average.

Dr. NORTON. Yes, that implies that they will have a larger than average impact.

Senator MITCHELL. Let me ask one question. I will ask Mr. Heffern, Mr. Martini, and Ms. Gass to comment on it.

Recognizing we are dealing in estimates and unknown figures, can you compare the cost of environmental damage that will result from our failure to control the sources of acid rain to the cost of controlling those sources at the point of emission?

Mr. HEFFERN. Senator Mitchell, I think it is a little hard to make that comparison from Minnesota's perspective and perhaps the national perspective. From Minnesota's perspective we do not have a good understanding of the extent of the problem in Minnesota. The extent of the problem in Minnesota is caused by Minnesota sources, and the extent of the problem in Minnesota is caused by sources outside of Minnesota, either from other parts of the country or from Canada.

It seems to me without an understanding of the dimensions of the problem it is a little hard to try to develop the full solutions and then attribute cost of those solutions. Therefore, I think it would be extremely difficult for Minnesota to come up with the kind of response for which we are asking.

Mr. MARTINI. I would agree with those comments and say that they apply to Wisconsin as well. In Wisconsin what we have done to try to estimate cost is to form a consortium of industrial sources, especially coal-fired plants and agencies, to jointly study the costs

of a number of different techniques in reducing sulfur, especially in the State of Wisconsin.

We have decided to estimate the cost of six different technologies for reducing sulfur dioxide for our Wisconsin sources within the next 6 months. Each utility will estimate for each installation the cost of employing these six different techniques to reduce sulfur. We do not have those estimates as yet. We estimate it is going to take approximately 50 percent reduction to at least hold our own and reduce the effect of acid deposition or at least stay the same.

However, we have no idea as to exactly how fast the lakes are acidifying and how much it is going to cost to control some of the sources in the United States.

Senator MITCHELL. I apologize; I am going to have to leave and go briefly to another hearing. In the meantime, Senator Stafford will Chair this hearing.

Senator STAFFORD [acting chairman]. Ladies and gentlemen, one of the problems we seem to face here in the Senate is that so often we are expected to be in three places at once. I know that Senator Mitchell has another committee to go to.

In presiding here temporarily I am aware of two other committees that I am supposed to be attending. I am not sure how many committees Senator Boschwitz has this morning, but we are thankful he is here now.

Senator, do you have any questions at this point?

Senator BOSCHWITZ. I am aware that we have these problems in Minnesota, particularly in northern Minnesota where the lakes are susceptible, as Mr. Heffern indicated.

I want to ask Dr. Norton a question. Are we now burning so much more coal that the problem has become more distinct or are we just becoming aware of the problem?

Senator Stafford is on the Environment Committee and perhaps has more background in this.

Why is it that this issue is just coming up now? It seems to me we are not burning quite as much coal or at least burning it a little more cleanly than we used to do.

Dr. NORTON. There certainly has been an increase in consumption of fossil fuels through time, but you are correct in your statement that the burning of coal has not increased appreciably. In fact, it took quite a dip for a while. It is making a comeback.

Perhaps most of the problem has been generated by the style in which the emissions have been emitted. The practice in years past was to emit your pollutant at low elevation with low stacks. Now we have the super stacks, the tall stacks, so that we have much wider dispersion of the pollutants, much greater long-range transport. Before we had pockets of intense pollution, and now we have a more regional effect.

Senator BOSCHWITZ. These large stacks were installed for the purpose of environmental consideration, were they not?

Dr. NORTON. They were probably installed as a result of concern over human health because of the intense local pollution with SO_x, NO_x, and particulates associated with fossil fuel burning. By injecting them higher into the atmosphere, you get rid of the local health problems but generate a regional acidic precipitation problem.

Senator BOSCHWITZ. Regarding some of the scrubbing and some of the cleanup that is now associated with these emissions, would that reduce the sulfur content of the emission?

Dr. NORTON. I am starting to walk on thin ice but I will go as far as I dare.

Scrubbing—and precipitators—removes a number of things. It removes particulates and it removes SO_x.

Senator BOSCHWITZ. What is SO_x?

Dr. NORTON. SO_x is the sulfur oxides that are emitted, largely SO_2.

The particulates themselves have, in some cases, a very ameliorating effect on the acidity of the effluent. The particulates tend to be alkaline. If they were allowed to mix with the materials coming out of the stacks, we would have less acidic precipitation. However, the reverse side of that coin is that we would in fact be injecting more heavy metals, toxic metals, into the atmosphere for dispersal. Therefore, it is a catch 22 situation to a certain extent.

Senator STAFFORD. Would the Senator yield?

Senator BOSCHWITZ. Yes.

Senator STAFFORD. It occurs to this Senator—and I would be interested in your comments—that what is triggering our really major interest now in acid rain has started with the so-called oil backout bill that the Senate considered a few months ago in which it was proposed that 80 eastern oil-burning generating plants be converted from oil to coal.

We had some controversy in the Senate, as you may recall, Senator Boschwitz, over the degree to which scrubbing equipment should be installed in the stacks as conversion from oil to coal occurred. It was the opinion of the Senator from Vermont that the technology was available to limit the various emissions which have caused acid rain so that in converting 80 large plants from oil to coal we at least would not increase the acid rain fallout on the northeastern part of the country, especially the northeastern seaboard.

The Senate did not agree with the Senator from Vermont to the extent of installing what I consider to be the necessary technology, which was not cheap.

The general proposition is that the more we convert from oil to coal, which I think we should do, the more acid rain we are going to create unless we do the job right and install the necessary technology either before coal is consumed in the boilers or remove the contaminants in the stacks after it is burned.

Am I correct generally in what I am saying? Would you care to comment on it?

Mr. MARTINI. In my opinion you are correct. The estimates I have seen estimate approximately 25 percent increase in acid rain precursors directly due to coal conversion. Inasmuch as it is such a regional and international problem, any increase in the total amount of acid rain precursors is significant to all the States in the eastern part of the United States in addition to Canada.

Senator STAFFORD. There seems to be no question but what we need to convert coal to get away from our dependence on foreign oil. However, at the same time if we have the technology—and this Senator believes we do—there is no excuse, in my opinion, for

converting to coal without doing the job right so that we do not increase acid rain fallout in the United States.

I will not comment further, Senator. Thank you for yielding.

Senator BOSCHWITZ. I do not remember the particulars of that debate. What was the added cost for each one of the 80 plants?

Senator STAFFORD. The total cost was somewhere in the nature of an additional $2 billion for all the 80 plants combined beyond the cost of the proposed scrubber technology that would have been installed under the plan which came out of committee.

There is no question but that it is an expensive process, but you have to weigh that, I think, against the health and welfare of the American people in making a change.

Senator BOSCHWITZ. The cost was about $25 million per installation?

Senator STAFFORD. Something like that.

Senator BOSCHWITZ. $25 million per installation.

What about the other parts of the world? Mr. Martini spoke about that and some other witness spoke about the impact on the Scandanavian countries. Just Norway and Sweden were mentioned. What about the impact on a country such as England where there has been a great deal of coal burning over a period of time? I address that question to Dr. Norton.

Dr. NORTON. With respect to England, at least the southern part of the two islands is blessed with having rocks and soils which have great acid-neutralizing capabilities. In terms of the quality of the surface waters at least, there has been virtually no widespread measurable impact.

However, in Scotland there are rocks that are somewhat like the rocks we find in New England, Norway, and Sweden. In fact, they have an acidic precipitation problem with measurable impact on surface waters there.

Senator BOSCHWITZ. What about on soils in southern England?

Dr. NORTON. I do not know of studies that have been performed. I would guess my vision of England is largely agricultural for vast tracks, which means the soils are mended by fertilizers, including lime, so that the chemistry of the soils would not be badly altered. That says nothing about direct impact on agricultural crops, but that will be addressed later.

Senator BOSCHWITZ. You mentioned that through the use of liming you were doing in Maine you could restore the pH balance in some of the lakes. Apparently then you can do that with respect to the ground as well?

Dr. NORTON. That is correct. I did not—or did not mean to say—that we are doing it in Maine, but there are States that are doing it.

Senator BOSCHWITZ. I see. I thought you said there were.

Mr. Martini, what causes the rain to be 10 times as acid or 100 times as acid? In the process of your testimony you talked about rains being 10 times or 100 times as acid. I am not quite sure as acid as what.

Mr. MARTINI. Natural rainfall is about pH 5.6 which means that it is slightly acidic naturally. The carbon dioxide in the air combines with water to form a weak carbonic acid in the atmosphere naturally, which is why rainfall is not neutral without addition of

pollution. When you add sulfur dioxide and other oxides and to some extent some hydrogen chloride, you get formation of acids because of the combination of these pollutants with water. They form secondary products, H_2SO_4, sulfuric acid and nitric acid, which causes the rain to become more acidic.

Depending on the amount of time that the pollutant has been in the atmosphere and the amount of moisture, the temperature, and other factors, it may get complete or only partial conversion of the pollutants to acid. Eventually these acids are either deposited in acid form, in sulfate form, or in particulate form, either dry or wet, on a variety of different environments where they can interact with the biological community and the chemical and physical parameters of that environment.

We are not certain what these transformations are, but we do know there is a direct relation between the increase in acid rain precursors and the increase in acidity in the precipitation.

Senator BOSCHWITZ. Dr. Norton, is most of the acid rain traceable to powerplants, to coal burned in powerplants? That is all that is spoken about.

Dr. NORTON. No, not all of it. I am not sure what the exact fractions are.

Senator BOSCHWITZ. Most of it?

Dr. NORTON. The significant sources of the precursors of sulfuric acid and nitric acid are the powerplants but also major industries which consume fossil fuels. The transportation industry is a very significant inputter to this problem. The smelting industry takes raw material out of the earth, sulfide minerals, and roasts them producing SO_2, which is emitted to the atmosphere.

I would like to add to my answer to an earlier question, which is, why do we have this increased acidity in the recent past because coal production and consumption has not gone up that much.

Senator BOSCHWITZ. Seemingly there have been some efforts to scrub or purify the emission.

Dr. NORTON. Oh, yes, and the precipitators for the particulates. However, one thing that has grown rather enormously is the transportation industry. The internal combustion engine takes nitrogen from the atmosphere and combines it with oxygen from the atmosphere and makes NO_2, which then makes nitric acid.

One-third, roughly, of the acid falling in the rain and snow in the eastern part of the country is from the internal combustion engine, just the process of passing air through the engine. On the west coast, in California, where they also have acidic rain, two-thirds of the acid can be attributed to the internal combustion engine. You only have to drive in downtown Los Angeles to see it.

Senator STAFFORD. Thank you very much, Senator. Thank you, panel members.

On behalf of the two committees, we express our deep appreciation to you for coming and helping us out today. Thank you very much.

The next witness will be Dr. Thomas D. Crocker, professor of economics, University of Wyoming.

The Chair welcomes Dr. Crocker. Please come forward and take the witness chair.

Doctor, being a northern New Englander, I am often reminded of my grandfather's advice. He was a Universalist minister who used to say, "Let thy speech be short that the memory thereof be long."

STATEMENT OF DR. THOMAS D. CROCKER, PROFESSOR OF ECONOMICS, UNIVERSITY OF WYOMING, LARAMIE, WYO.

Dr. CROCKER. I assure you it will stay under 10 minutes. Whether the memory will be long is another question.

My name is Thomas D. Crocker. I am professor of economics and director of the Resource and Environmental Economics Laboratory at the University of Wyoming. I previously have been on the faculties of the University of Wisconsin and the University of California. I have worked in the area of environmental economics for approximately 15 years.

There has recently been increased awareness that some environmental pollution problems involve more than the local affronts to life and property imposed by the traditional urban pollutants. Partly because of the broad geographical and temporal scope of their plausible effects, some also lead to progressive deterioration in the Earth's ecosystems and the flows of pleasures and life support services issuing from them. Acid precipitation appears to be one of the latter pollutants. Some ecosystems are being washed in a continuing series of acid baths.

I wish to summarize the draft report containing results of an EPA-supported attempt by my colleagues and me to assess the economic importance of some of the effects of acid precipitation. On the basis of our survey and synthesis of a fairly large volume of physical and biological science literature and stock price and output information, we have concluded that the 1978 cost of the effects of acid precipitation on the current annual yields of existing economic activities in the eastern third of the United States is no more than $5 billion.

Our best estimates are that $2 billion is in materials effects, $1.75 billion is in forest ecosystem effects; $1 billion is in direct agricultural effects, $0.25 billion is in aquatic ecosystem effects, and $0.10 billion is in other effects, including health and water supply system effects.

With the exception of a few instances where we were able to draw analogies with the results of other studies using more robust economic assessment techniques, these estimates disregard acid precipitation-induced price, activity, and location changes. They are, therefore, incomplete.

If acid precipitation events continue, this ranking of effects could readily change. For example, aquatic ecosystems currently have a low position only because the geographical scope and severity of aquatic acidification does not yet seem to be large enough to reduce greatly the possibility of people moving to other fishing and hunting sites. New York State contains many more than the 100 or 150 or so Adirondack lakes that are now devoid of fish life.

Because of the water and soil treatment facilities already in place that can readily be adapted to handle liming procedures, the costs of acid precipitation effects on human health, agricultural soils, and household commercial and industrial water supply sys-

tems are now and are likely to continue to be insignificant compared to the other effects.

However, I have seen nothing whatsoever which convinces me that at this time large-scale liming of either aquatic or forest ecosystems is technically or economically feasible. Water bodies are too individualistic. No one has explained how to plow in amongst tree trunks and roots.

The preceding simple accounting of the cost impacts of acid precipitation upon the current annual yields of existing economic activities does not in my view suggest the really significant potential and actual economic effects.

The picture of reality that this accounting and others like it offers might well be badly distorted and misleading. It neglects at least two important features of the effects of acid precipitation on ecosystems. For brevity, I shall call these the all-or-nothing effect and the now-or-never effect.

Their existence might make economically unappealing those compromise solutions in which balance and recognition of tradeoffs is sought between the cost of environmental damages and the cost of controlling precursor emissions. Economics may ultimately justify only either extremely stringent controls or minimal or no controls on these precursors.

The all-or-nothing effect occurs when if an ecosystem is unpolluted a little bit of pollution does a great deal of harm, but if it is already polluted a bit more pollution will not matter much.

Stated alternatively, control benefits increase at an increasing rate with progressively more stringent controls on sources of acid precursor emissions. Though still scattered, empirical evidence is beginning to accumulate that acid precipitation and the fine particulates contributing to it impact in this way upon aquatic ecosystems, atmospheric visibility, and forest esthetics.

Thus, if this pattern of acid precipitation damages is ultimately found to occur frequently, research into economic losses and the natural science research which supports it should concentrate on those systems just entering the first stages of acidification. Systems which are already moderately acidified are likely to cost too much to restore if society is to obtain any substantial benefits from them.

The now-or-never effect exists because many natural scientists have evidence that acid precipitation irreversibly leaches plant nutrients from forest soils, irreversibly concentrates heavy metals and other toxins in aquatic and terrestrial ecosystems, irreversibly destroys nitrogen-fixing bacteria, and does a number of other irrevocable deeds.

The built-in acid buffers of natural ecosystems are being worn away. This wearing away means that future opportunities to cut trees, catch fish, and enjoy scenery are being mined. Economic assessments which consider only the losses to current economic activities will not reflect the losses due to this depletion.

Again, this irreversibility phenomenon suggests that research should be focused on those systems on the verge of acidification. Already acidified systems are of no policy interest if there are no economic means to bring about their recovery.

Irreversibilities introduce the now-or-never effect if the relative values of remaining unpolluted environments are likely to increase

in the future. This increase could occur because of increasing demands for unpolluted environments or because of increasing availabilities of manufactured goods.

A future dollar is less valuable than that same dollar available right now. Delaying acid precursor emission will thus make the control costs that are saved appear less valuable from the perspective of the present.

During this delay, since the unacidified systems already exist, the life support and amenity services they produce continue unabated. Thus, if the value of unpolluted environments is likely to increase in the future, the economic gains from failing to control acid precursor emissions will never be greater than they are now. Conversely, every delay in deciding what actions to take makes stringent controls on precursor emissions more economic.

Finally, I should like to note that generally economic techniques are lacking to capture the values that people obviously attach to the novelty and flexibility that unstressed ecosystems provide human experience. By reducing species numbers, acid precipitation simplifies ecosystems, thus narrowing human opportunities to experience novelty and flexibility.

I hope that was within 10 minutes.

Senator STAFFORD. Very well done. Your prepared statement in its entirety will be made part of the hearing record.

[The prepared statement of Dr. Crocker follows:]

STATEMENT BY
DR. THOMAS D. CROCKER
PROFESSOR OF ECONOMICS
UNIVERSITY OF WYOMING, LARAMIE
BEFORE
U.S. SENATE SMALL BUSINESS COMMITTEE
AND
U.S. SENATE COMMITTEE ON ENVIRONMENT
AND PUBLIC WORKS

September 23, 1980

I. INTRODUCTION

There has recently been increased awareness that environmental pollution problems involve more than the direct affronts to life and property imposed by the traditional urban pollutants. Partly because of the broad geographical and temporal scope of their plausible effects, some also lead to progressive deterioration in the strength of the earth's ecosystem scaffolding and the flow of pleasures and life support services issuing from it. Acid precipitation appears to be one of the latter pollutants: some parts of the scaffolding are being washed in a continuing series of acid baths. Irritated places have appeared. I wish to report the first results of an attempt by my colleagues and me to assess the economic import of these irritations.

I shall initially present for the eastern third of the United States an order-of-magnitude estimate of the value of acid precipitation effects on the current annual yields of existing economic activities. These and similar estimates, probably including those to be related later in this hearing, fail, I believe, to capture the full severity of the irritation. I shall explain why, hoping thereby that the Committee will see fit to encourage those types of economic and ecological research that could establish quantitatively the extent to which the estimates are incomplete.

II. VALUE OF EFFECTS ON CURRENT ANNUAL YIELDS

On the basis of our survey and synthesis of a fairly large volume of physical and biological science literature, and stock, price, and output information, we have concluded that the 1978 value of the effects of acid precipitation on the current annual yields of existing economic activities in the eastern third of the United States is no more than $5 billion. Our best estimates are that $2 billion is in materials effects, $1.75 billion is in forest ecosystem effects, $1 billion is in direct agricultural effects,

$0.25 billion is in aquatic ecosystem effects, and $0.10 billion is in other effects, including health and water supply system effects. With the exception of a few instances where analogies could be drawn with the results of studies that applied more robust economic assessment techniques, these estimates disregard acid precipitation-induced price, activity, and location changes. They therefore cannot be justified indefinitely.

If acid precipitation events continue, certain sectors could readily climb in the above ranking. For example, aquatic ecosystems currently have a relatively low position only because the geographical scope and severity of aquatic acidification does not yet seem to be large enough to reduce substitution possibilities greatly across fresh-water fishing and hunting sites. Because of the water and soil treatment facilities already in place that can readily be adapted to handle liming procedures, the acid precipitation control benefits accruing due to the prevention of human health effects, indirect agricultural effects, and household, commercial, and industrial water supply system effects are now and are likely to continue to be insignificant compared to the other classes of effects. Large-scale liming of aquatic and forest ecosystems appears to be neither technically nor economically feasible, however.

III. THE IMPORTANT EFFECTS AND THEIR CONTROL IMPLICATIONS

We are unconvinced that either the above ordering or the absolute magnitude estimates of the current annual benefits constitute the really important issues to consider when evaluating the acid precipitation problem. Indeed, we are left with the disquieting feeling that the effects for which one may feel secure using our simple, or even the much more sophisticated but still conventional, methods of economic analysis are those having the least

economic significance: the ultimate economic losses could be much larger. In fact, ours and similar estimates can be a misleading basis for control decisions for at least three reasons: incremental damages that decline with increasing acidification; irreversibilities; and the values of natural resource assortments that our techniques fail to capture.

Users of conventional economic techniques of assessing the value of ecosystem components, such as a tree, typically assume that the components are valued independently of the environmental state from which they come. Pollution damages to these components are customarily treated as increasing at an increasing rate so that each additional unit of pollution causes progressively greater damages. Moreover, these damages are assumed to be reversible, and, by reducing the level of pollution, recovery is presumed to occur along the same path as did the damages. This standard representation leads to conclusions which justify bearing some immediate environmental damages in order to obtain some of the immediate benefits that a productive but polluting activity confers. In short, compromise solutions favoring "balance" and recognition of "tradeoffs" among the interests of competing parties dominate. The ecosystem effects of acid precipitation may not conform to the standard representation; the usual compromise solutions may therefore be inappropriate.

Unacidified aquatic ecosystems are often affected much more dramatically by a given addition of acid precipitation than are already acidified systems. Insofar as atmospheric visibility and the aesthetic aspects of forests are harmed by the fine particles that contribute to acid precipitation, empirical evidence is beginning to accumulate that these systems too respond in a similar fashion. For example, Butler, et al.* in a 1973 study of Pennsylvania

*Butler, R.L., et al., Fish and Food Organisms in Acid Mine Waters of Pennsylvania, USEPA Ecological Research Series (EPA-R3-73-032, Washington, D.C.: USGPO (Feb. 1973).

streams suffering from acid mine drainage, found that when the level of acidity was very low, 24 of 25 sections of different streams sampled had fish present. An approximate doubling of acidity then resulted in a halving of the number of sections with fish; however, to halve again the number of sections with fish required a nearly five-fold increase in the level of acidity. Similarly, 116 fish species were present when acidity levels were very low. A doubling of this low level reduced the number of species to 48. Less than another doubling only reduced the 48 species to 41. In other words, if the system is clean, a bit of acid does a great deal of harm; but if it is already acidic, a bit more acid will not matter much.

These research findings, and others like them for aquatic ecosystems, atmospheric visibility, and forest aesthetics, imply that incremental benefits increase with progressively more stringent controls on acid precursors. If the environment were already acidified, a large control cost burden with relatively few benefits would have to be borne prior to reacquiring the benefits of a relatively nonacidified state. As a result, decisions to control acid precipitation may have strong "all-or-nothing" elements: intermediate control measures can lead to burdensome control costs while generating few environmental benefits. Literal interpretations of prices applying to current annual yields from economic activities operating in high levels of acidification can wrongly guarantee that these levels will continue: the ecosystem destruction wrought has been so great that the benefits from small amounts of reduced acidification appear minor. To use a reasonable example, reductions in acidity cannot increase the economic benefits of recreational fishing when there are no fish around who can reproduce.

The picture of reality offered by the use of only the values of current annual yields of existing economic activities to assess the benefits of

controlling acid precipitation is yet more distorted by irreversible terrestrial and aquatic ecosystem effects. Natural science literature is replete with examples of acidification-induced leaching away of plant nutrients, concentrations of phytotoxins, including heavy metals, destruction of nitrogen-fixing bacteria, and the spallation of soil-binding agents. I have seen nothing whatsoever outside managed agricultural systems which convinces me that large-scale liming can reverse these and other effects in either aquatic or terrestrial systems. The built-in buffers of natural ecosystems are irreversibly being worn away. This wearing away means that future opportunities to cut trees, catch fish, and enjoy scenery are being removed. Any depletion of future economic opportunities is no less a cost than is the impact of acid precipitation upon the current yields derived from existing economic activities. To see this, consider the job prospects of an oil company executive who bases his decision of whether to extract a barrel of oil from his company's reserves on no more than current costs of extraction and the current price of a barrel of oil. If extraction costs were expected to remain constant, while per barrel price were expected to triple within the month, by extracting now he certainly would not endear himself to company owners. The owners would have preferred that he forego immediate gains in order to retain the opportunity to acquire much greater later gains. Similarly, assessments which value reductions in current yields from existing economic activities, while disregarding depletion effects, will improperly dismiss an important economic feature of the effects of acid precipitation.

If the cost-saving in controlling the emissions that cause acidification decline over time relative to the benefits of natural environments, the irreversible effects of acidification, when combined with a positive interest or discount rate, lend the acidification issue a "now-or-never" character. With

a positive discount rate, any delay in causing acidification will only make it look progressively less attractive. Not only are the relative benefits of acidification declining over time, by assumption, but the positive discount rate causes the present value of acidification benefits to be reduced with every delay. In the meantime, since the unacidified systems already exist, the material goods and the life support and amenity services they produce continue unabated. Therefore, assuming constant or decreased future control costs, the net gains from ecosystem acidification will never be greater than they now are.

The presence of declining relative benefits of acidification (or increasing relative benefits for preserving natural environments) is a necessary condition for the above conclusion. As set forth by several economists, two key propositions lead to a prediction of increasing relative benefits for natural environments. First, environments that have remained unsullied by man's activities and artifacts are superior goods: as real incomes increase, the willingness-to-pay for natural environments increases at an even greater rate. Man-made substitutes become progressively less attractive. Second, because of the imperfect reproducibility of natural phenomena, technological change tends to reduce the supply prices for man-made goods relative to the supply prices for natural environments. The obvious general conclusion is that both the relative cost of supplying and the willingness-to-pay for natural environments are going to increase progressively over time. Both of these countervailing supply and demand forces imply that the citizenry will attach increasing values to natural environments relative to fabricated goods.

Irreversibilities and incremental benefits that increase as acid precipitation is curtailed suggest that the use of the economic values of current yields from existing activities will underestimate the benefits of

controlling acid precipitation. Yet another source of underestimation and misinformation exists, whether or not attention is limited only to current yields from existing activities. In particular, there are inadequacies in the supporting material on ecosystem responses that the ecologist can offer the economist, and inadequacies in what the economist can do with whatever the ecologist offers him. Ecologists point out that, as practiced, techniques for assessing the economic benefits of pollution control disregard, for example, the contributions that mayflies and their peers make to the well-being of trout, and therefore that the ultimate effects of pollution on trout, via mayflies, is unrecognized. This assertion of the ecologists is correct, but not because of the absence of a technique of economic analysis to capture mayfly contributions: the historical emphasis of ecology on short-run, transient movements in the population abundances of single species does not fit readily into the framework of benefit-cost analysis. The emphasis also usually fails to provide information on the contribution mayflies make to the welfare of the trout that humans value. Economic analysis cannot attach values to ralationships which have not been quantitatively described.

Ecologists also point out that economic assessment techniques fail to capture the novelty and stability that ecosystems with a variety of components offer. Acid precipitation tends to simplify ecosystems by reducing the number of species they embody, thus reducing human opportunities for experiencing novelty while also increasing the susceptibility of human activities involving ecosystems to environmental shocks. Economists do not know the relevance of these issues of ecosystem assortments because empirical techniques have not been developed to value them.

IV. IMPLICATIONS FOR RESEARCH

Though the applicable physical and biological facts and processes of acidification are by no means fully comprehended, the basic outlines and major

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steps of the systems are reasonably well-known. In particular, the acid precursors and their emission quantities, the environmental sinks for acidifying depositions, the environmental changes that could ultimately be wrought by acidification, and the likely regional sequence of changes in the qualitative integrity of ecosystems have all been identified. In spite of occasional expressions of disbelief (e.g. Perhac*), there is broad consensus about the direction in which to move to reduce the physical and biological manifestations of acidification. However, the amount of movement called for has no consensus. Emitter regions concerned about declines in their industrial economies call for small or zero movements, while sufferer regions worried about declines in their natural environments and the human activities dependent on them call for large movements. Identification of the costs and benefits of various degrees of movement is by no means a sufficient basis for establishing a political consensus. It can nevertheless remove a major barrier to establishing this consensus. The benefits of various degrees of clean-up will probably suffer severely in the scale of relative benefits and costs if attention is focused solely on values of small acidification-induced effects on the current yields of existing economic activities. The decisionmaker must expand the scope of his vision of control benefits to include discrete rather than small alterations in existing states as well as losses of current and future opportunities to experience novelty and the materials and life support services issuing from ecosystems. If this is to be accomplished, the following types of research into the benefits of controlling acid precipitation are minimally necessary.

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*Perhac, R.M., Transcript of testimony before the National Commission on Air Quality, Washington, D.C. (Oct. 5, 1979).

1) The biological and physical sciences must quantitatively demonstrate how ecosystem components such as soil microbes, mayflies, etc., contribute to or detract from the well-being of those components such as trout, trees, and lettuce that humans directly value. Research into acidification-induced basic biochemical and physiological processes has rarely succeeded in making these demonstrations.

2) Natural science research into acidification-induced ecosystem responses should be distributed widely across a variety of ecosystem types, locations, dosages, and temporal durations. In general, reasonably accurate knowledge of system responses under a wide variety of plausible circumstances will be much more useful for benefits assessment than will extremely precise knowledge about responses under one or only a few circumstances.

3) The frequency with which irreversibilities and declining incremental acidification-induced damages occur in ecosystems must be established. If either or both occur frequently, then natural science research should concentrate on ecosystems on the verge of acidification. Already-acidified systems might be beyond saving on any large scale basis. Even if they could be restored, the occurrence of declining incremental damages will often mean that they are not worth restoring. In short, benefits are likely to be greatest if control and research are centered upon preventing currently nonacidified systems from becoming acidified.

4) Current techniques of economic analysis generally fail to capture the benefits that ecosystem diversity and stability offer human beings. Acid precipitation reduces this diversity and stability. Economic methods that capture this reduction must be developed and empirically implemented.

Senator STAFFORD. In your judgment how does the cost of environmental damage compare to the cost of controlling the sources of pollution that are producing acid rain?

Dr. CROCKER. My judgment would be, if one takes into account all these factors of which I spoke which indicate in my view that the existing prices for these damages that acid precip is causing are misleading and underestimate the effects, I would say the benefits of control exceed the current cost of control, although by how much I would not dare say.

Senator STAFFORD. Thank you. I have one final observation and possibly a question.

In discussing a minute ago the oil back-out legislation involving the 80 plants which are to be converted from oil to coal, I guess it would be fair to say that some acid rain is created by burning oil itself since many of the same substances are in fuel oil that are in coal that cause acid rain. The principal problem with the whole program there to me was the fact that the use of coal as contemplated in the switchover was going to increase the acid rain by about 15 percent. In other words, instead of maintaining a level of output of contaminants by the use of scrubber techniques or prior combustion techniques, the coal-burning conversions were going to allow additional contaminants to reach the atmosphere that would have increased acid rain 15 percent over the eastern seaboard. That was what I objected to very strongly then and still do.

As we transfer further oil-burning generating plants or large individual factories from oil to coal, unless we install the proper scrubber techniques we will further increase the outfall of acid rain on the country. Would that be a fair assumption?

Dr. CROCKER. I am really not qualified as an economist to speak to that, sir.

Senator STAFFORD. Thank you very much for your comments. The committees are grateful to you.

Next the committees will hear from a panel on tourism and recreation. The panel of witnesses consists of Mr. John Alward, who is a resort owner at Eagle River, Wis.; Mr. James W. Gracie, chairman of resource management and protection committee, Trout Unlimited; and Mr. Bill Roden, who is a resort owner at Diamond Point, N.Y.

If the panel will come to the witness table, the Chair will welcome you on behalf of both of the committees involved and leave to you the protocol with which you may speak.

In view of our severe time constraints, we would ask you to try to limit your speeches to a few minutes in summary. Your entire remarks will be made part of the record.

We are ready to hear you as you may wish.

STATEMENT OF JOHN ALWARD, RESORT OWNER, EAGLE RIVER, WIS.

Mr. ALWARD. Thank you, Senator Stafford. I am very happy to be here.

I want to introduce myself. I am John Alward, a resort owner in northern Wisconsin in Vilas County in the city of Eagle River.

Our family-operated resort has sales of around a half million dollars and a payroll of around $100,000.

I am a past president and still a board member of the Wisconsin Hotel Association—Wisconsin Innkeepers Association—the same with the Wisconsin Resort Association—Wisconsin Recreation Industries—past president of the chamber of commerce of our town, and a 25-year perfect attendance as a Rotarian.

Why am I here? I have been invited to come and tell you a little bit about the business of Vilas County. Vilas County is in the extreme north center section of the State, totaling 650,000 acres with land area of 557,000 acres.

What we are talking about today and what you want to know is, what can affect our waters? We have 1,200 acres of rivers and streams, with 1,322 lakes, which comprise 92,000 acres, that gives us 93,000 acres of water or 14 percent of the area in Vilas County.

Vilas County is basically 100 percent tourism, and depends upon the tourists to make ends meet. It is very similar to our State of Wisconsin. In the State of Wisconsin tourism is our No. 2 industry. However, I am talking about Vilas County.

Vilas County has 545-plus hotels, motels, resorts, which comprise over 5,500 rooms, 213 restaurants and eating establishments. Over 9,000 boats are registered in our county.

In 1978 over 7 million fingerling fish were put into our waters. Fishing licenses sold in our county alone were over the 50,000 figure, last year.

In a questionnaire that was put out by the University of Wisconsin and our county agents in the courthouse they asked questions of the tourists as to why they came to our county? Thirty-five percent of them said that they came to Vilas County for fishing. That is an important fact with our water resources.

Thirteen percent came for boating. Two percent came for water skiing. However, our main thing with us today is the fishing.

Our tourism money coming into Vilas County is over $112 million, with sales tax coming into the coffer of the county of over $2.5 million in any one year.

Backing up those statements, the deposits in the banks in Oneida and Vilas Counties are over $228 million in the two counties. Vilas and Oneida Counties are very similar in the number of lakes, businesses, and so forth, so cutting that figure in half is $114 million. That is close to the preparation figures which came out of the courthouse and the university. They said $112 million and our bank deposits say $114 million. We are on the right track on that.

Thirty-five percent of the tourists from that inquiry sent out by the university were people who came to our county to fish. If we take 35 percent of those figures I just gave you, the $112 million in tourism money brought into our county, 35 percent of that would be lost if acid rain really affects our water.

You have heard the reports from the others. I know you will hear many more reports before this committee meeting is over about what acid rain can do and is doing. Potentially we have a drastic situation facing us.

We in Vilas County could lose 35 percent of our business. Thirty-five percent of that $112 million would be in the $39 million class. That is a lot of money to lose. Therefore, acid rain is a very, very important thing for us to think about in our county, in our State, and in our Nation.

To go back to my own resort, the Chanticleer Inn, it is a family-operated resort. We have been operating now for 29 years-plus, now in our 30th year.

As I said, we are in a half million dollars gross sales category. If I took 35 percent of our business out for fishing, no fishermen coming up and the like, and we dropped $175,000 of our income, I do not think the banks would be very interested in what our future business would be. Therefore, I think this acid rain is a very, very, very important thing to us all over and to us especially in Vilas County and to me at the Chanticleer Inn.

In summarizing the whole thing, I look at it this way: Vilas County would be a place to come to with beautiful, clear lakes, but we would not have anything growing in those lakes. We would have no fish. It would be a nice place to take pictures, but I think it would be half dead.

Thank you.

Senator STAFFORD. Thank you very much, Mr. Alward.

STATEMENT OF WILLIAM M. RODEN, RESORT OWNER, DIAMOND POINT, N.Y.

Mr. RODEN. I am a resort owner, too. Would you like me to tell another resort story?

Senator STAFFORD. I would like to hear it. I come from a resort State myself.

Mr. RODEN. Senator, it is nice to talk to a Senator Stafford. My State senator at home is Senator Stafford. I often talk to him.

Senator STAFFORD. Is that Ron Stafford?

Mr. RODEN. Yes.

Senator STAFFORD. I know him quite well.

Mr. RODEN. We are good friends.

It is nice to be here, sir.

My name is William Roden. I am a resort owner in New York's Adirondack Mountains. I have been asked by the Adirondack Association to speak to you today.

My wife and I operate Trout Lake Club, a family housekeeping cottage resort on a small lake in the southeastern part of the Adirondack Park. My family has been at this location since 1924, and my children are the fourth generation of Rodens to work at our resort.

I'm also a newspaper columnist. I write a weekly outdoor column known as the "Adirondack Sportsman," which is carried regularly in three northern New York papers and, on occasion, in as many as eight more.

I'm an ardent and frequent fisherman and hunter in our region and active in fish and wildlife and conservation organizations on the local, regional, and State levels.

On behalf of myself, my friends, my neighbors, and fellow fishermen, I extend thanks for the invitation to be here today. I should also tell you that when they heard I was coming they rallied around and supplied me with some wonderful information.

On the other hand, I am afraid I am going to leave that in the prepared statement, inasmuch as you want us to be brief, and count on it being included in the record. I will talk extemporaneously about some things.

First of all, welcome Minnesota, Wisconsin, Michigan. We are delighted to have you with us—not that we want you to have acid rain, but we need your support. You are today where 10 years ago New York State was.

Shortly after high towers, smokestacks, and scrubbers were put in in the Midwest we began to see acid rain. We were naive; we really thought it was the blowdown that we had had in 1950 which devastated some 200,000 acres of woodland. We thought perhaps it was the rotting wood, but we found out later that it was not. It is acid rain.

I am going to be controversial. You asked earlier, sir, who was causing it, what the origination of it was. I have here a page from Outdoors Unlimited, which is distributed by the Outdoor Writers Association of America. It reports on a Bass Research Foundation report which says very clearly, "Over 80 percent of the acid precipitation comes from the generation of electric power with about 15 percent being industrial and less than 5 percent from all other sources, including your car."

Sir, please don't argue with me. Talk to the Bass Foundation. I am quoting their figures.

Some of you may have heard—I hope all of you have heard—of the "I Love New York" campaign. For your information, in New York State we had last year, 1979, some 1.375 million anglers who fished in our State. That came to between $518 million and $601 million in terms of expenditures.

When we promote New York State and love New York State, these are only two of the fishing booklets that are being distributed. Fishing is a large part of our economy and a really important part of our recreational effort. I have given some of these to the staff if you wish to pick them up.

I will also point out that in my county, Warren County, a county which has a gross population of something under 100,000 in the winter—in the summertime it is a little different, thank goodness—we are promoting to the tune of almost $200,000 our recreation and resort industry. This is a fishing booklet, 1 of 3, that my county has put out. In our area and in our county fishing is a basic and important part of our economy.

It is impossible for me to give you a specific figure for the part of the fresh water fishery of New York State that is Adirondack oriented. Just by reading these booklets you will see that it is substantial.

In our Adirondack area there are a total of 2,877 individual lakes and ponds encompassing an area of 282,154 surface acres. New York's portion of Lake Champlain is not included in this figure. The world famous 28,000-acre Lake George is.

So that you will appreciate the significance of our problem, the latest count we have—and you heard mentioned in Commissioner Flack's testimony earlier 170—the latest count that we have from last year's evaluation is that 264 lakes and ponds with 11,508 surface acres no longer have a sportfishery and many do not support aquatic life of any sort, including fish, crayfish, mussels, salamanders, et cetera.

Please remember these figures. That in 1 year represents an increase of 52 lakes and ponds with a total of 1,158 acres. This cannot go on for much longer. The very simple reason is that we are running out of little ponds. We are now into the 1,000-acre pond size going acid.

For example—and I hate to name it but I shall because they are brave people there—Big Moose Lake, the southwestern Adirondacks, 1,300 surface acres, has a pH reading of 4.17. President Grover Cleveland fished in Big Moose Lake, so it had a fishery in the 1800's, a notable fishery. There is none now.

A biologist gave me this statement just last week:

> With that kind of a pH I would expect no sport fishery to be possible for all practical purposes. It is much too large for a liming program. As far as the Department of Environmental Conservation is concerned, nothing can be done.

Liming is not a viable alternative when you get into this size.

I am going to skip over some good stories and some bad stories.

Last week I attended the New York State Conservation Council annual meeting in Niagara Falls. Incidentally, I saw Love Canal. I can talk about that, but I won't today; it is not the time. It is a frightening, sad experience to see it.

A friend stopped me and he wanted to tell me a story. He was a trapper. Last year he went into an area where he has trapped for many years successfully. He did not think of it at the time, but his success was zero. His traps were primarily for weasel, mink, otter, fisher, and raccoon. He caught nothing.

Then he realized he was in an acid rain disaster zone, as the local people call it. These were fish eaters that he was seeking. They had moved because there were no fish.

This is a byproduct that we do not even think about; $12 million a year is realized by trappers in New York State. There are some 22,000 trapping licenses sold.

Remember, those fish eaters that moved out of the area where this trapper was went someplace else, not an unpopulated place. You cannot take one population, put it in another populated area, and expect all to survive. The environment will support only so many fish and only so many wildlife. Something had to give. It is sad. It is just tragic really, an unmeasurable decline in the quality of life.

You had a good report on forestry. I would just remind you that the largest year-round industry in the Adirondack area is wood products. While we do not expect to lose all the trees to this problem, we do expect slower growth.

Mind you, our woodlands are on a sustained yield basis. Every 20 years there is a harvest of some sort. If that goes to every 25 years or even every 26 or 27 or 30 years, it is a significant economic effect. It may be a disastrous effect.

Let me tell one more quick story. It is a story of a resort owner to whom I talked last week. Once again, unfortunately, it is in Big Moose. As I say, they are brave and they are telling the facts as they are.

There was a taste in his water one morning. He tried it. Then he stopped. He took it and had it analyzed. He found that there was a high content of copper and lead in it. This was unheard of because this was spring water. Therefore, they went to the spring and there was nothing wrong there, but a test showed a very low pH, high acid content. The laboratory has told him that the pH from his pure spring water is leaching copper and lead out of his water system to the extent where it is a danger to human health.

He is not the only one in that lake basin. This is being discovered in other springs, other bodies of water.

Somebody mentioned earlier that it is a very real possibility. Here it has actually happened. This gentleman has a problem. He solved it by putting his spring water through crushed limestone before it goes into his house water system.

Think of that need in terms of hundreds of thousands of homes, resorts, and so on, and estimate the cost.

You have asked what might be done. I have some copies of this statement. Our DEC commissioner appeared before a House committee in February and made some suggestions, one of which includes taking corrective measures at all powerplants, including ours in New York State, for someone downwind of ours is undoubtedly receiving some of our acid.

I have here only one copy of this report, but I would like to give it to the committee. Perhaps they would make copies and distribute it to the members. It is a report on acid precipitation by Dr. Anne LaBastille, a member of our Adirondack Park Agency. It is short, concise, and addresses itself to the major areas of concern. I think it would be very instructive, particularly for laymen such as yourselves.

Senator STAFFORD. Thank you very much. We will have that made a part of the hearing record as well as distributing copies of it. Also, your prepared statement in its entirety will be made part of the hearing record.

[The information referred to follows:]

Statement by William H. Roden
For the Small Business Committee
Environment and Public Works Committee
U. S. Senate

My name is William Roden. I am a resort owner in New York's Adirondack Mountains. I have been asked by the Adirondack Association to speak to you today. My wife and I operate Trout Lake Club, a family housekeeping cottage resort on a small lake in the southeastern part of the Adirondack Park. My family has been at this location since 1924 and my children are the fourth generation of Rodens to work at our resort. I'm also a newspaper columnist--I write a weekly outdoor column known as the "Adirondack Sportsman" which is carried regularly in three northern New York papers and, on occasion, in as many as eight more. I'm an ardent and frequent fisherman and hunter in our region; and active in fish and wildlife and conservation organizations on the local, regional and state levels. On behalf of myself, my friends and neighbors and fellow fishermen, I extend thanks for the invitation to be here today. I should also tell you that when they heard I was coming they rallied around and supplied me with much information on the problems they are experiencing.

Our lake, Trout Lake, still has a pH of over 7 and is, therefore, not yet affected by acid precipitation or what we laymen call acid rain. However, just 30 miles to my north a friend of mine owns a camp on a small body of water called Lincoln Pond. Out of curiosity he took readings of his pond. In '77 it was 7.2; in '78 it was 7.0; in '79 the pH was 6.8 and, fortunately, it has held this level in 1980.

To the west of me is Canada Lake, a body of water with a surface area of some 535 acres, formerly known for its bass fishing. It is a very popular recreation lake with a number of resorts and many summer cottages on its shore. Today the bass are gone. The reading is down to 5.2 and the fishermen from that area are understandably angry. The winds from the west that cross Canada Lake cross Trout Lake

and I must, therefore, ask myself how long before our lake turns. This past summer guests at my resort had fantastic fishing--bass, and lake trout for those who know how to catch them in the cold deep water. Dozens of bass were weighed at our Beach Bar in excess of 2 pounds and three were over 5#. As I'm sure you have been told, bass are one of the first species to disappear as the pH of a body of water drops. How long will it be before those who vacation with us for the family activities and the fishing will begin to think of going elsewhere? The warning is already there in my backyard--a bronze bell that glistened in the sun for 35 years shines no more--it has turned green during the last 3 years.

You have asked me to present the viewpoint of the small businessman and give you some idea of the economic impact of acid rain on our area. It is difficult to cover all aspects and you must tolerate rough figures. We do have some studies which indicate the value of fishing to the New York State economy. In 1979 it was estimated that there were 1,375,000[2] anglers who fished in New York State. The value of this activity to our economy is estimated by our Department of Environmental Conservation researchers at somewhere between $8 million and 60[2] million dollars in 1979.

It is impossible for me to give you a specific figure for the part of that fresh water fishery that is Adirondack-oriented--it would be substantial, for in the Adirondack area there are a total of 2877 individual lakes and ponds encompassing 282,150 surface acres. New York State's portion of Lake Champlain is not included in this figure but world-famous 28,000-acre Lake George is. So you will appreciate the significance of our problem, the latest count we have is that 264 lakes and ponds with 11,338 surface acres no longer support aquatic life of any sort including fish, crayfish, mussels, salamanders, etc.

Please understand also the rate at which this problem is assaulting us--52 ponds with a total of 1,150 acres were among those measured that turned acid in the last year.

Because the acid situation was first discovered in the Adirondacks in remote, high-elevation ponds, there is a tendency to think that they are the only ones affected. This is not so. We now have a number of lakes in the 1,000-acre category at lower elevations which are sterile. There are a number of resort lakes which are presently on a rapid down-trend and are expected to lose their ability to support fish life in the near future. Canada Lake, mentioned before, Big Tupper Lake and Cranberry Lake (fifth largest in the Adirondack Park) are three well-known Adirondack resort lakes that are currently seriously threatened.,

One of the largest bodies of water with a serious acid problem is Big Moose Lake in Herkimer County in the western part of the Adirondacks. The surface of Big Moose is in excess of 1300 acres. It once had an outstanding fishery including brook trout, lake trout, and bass. President Grover Cleveland was very familiar with Big Moose Lake and fished it. He visited Dart Lake Lodge which was a small lakeside resort on the outlet stream of Big Moose Lake. The pH reading for Big Moose Lake today is 4.17. I'm sure you've been told by professionals who have testified before you previously such waters will support no fish life. Said one of our fishery biologists recently, "With that kind of a pH, I would expect no sport fishery to be possible for all practical purposes. Much too large for a liming program. As far as the Department of Environmental Conservation is concerned, nothing can be done."

This is a book from my Adirondack Library. It was published in 1941. The author, Leighton Brewer, is unknown to me but the title, VIRGIN WATER, caught my eye as a fisherman. Mr. Brewer was in the High Peaks of the Adirondacks. He writes:

"The story of the Flowedlands is also instructive. As I have already mentioned, it was formerly a swamp, but converted by a five-foot dam into a lake some three quarters of a mile in length. Through this lake flows the Opalescent River, which is, in fact, the main branch of the Hudson, only a few miles below where, as Feldspar Brook, it bubbles out of the ground at Lake Tear-of-the-Clouds.

"For some time no signs of fish appeared, although Lake Colden, just above, was overstocked with trout. Then one July morning about five years after the dam had been built, someone passing across noticed large trout rising, whereupon he put his rod together and proceeded to take five fish totaling 13½ pounds. These fish multiplied very fast, for in a few years the lake was just boiling with trout from 1 to 2½ pounds and a certain number of bigger ones.

"They grew rapidly, for all those caught were very fat and had small heads, indicating that they were young fish. This lake was soon fished without respite from the first of June until the last day of August, with an average of three rods a day; and I have estimated the annual toll was more than five thousand trout. Yet it continued to yield more and better fish than any other lake in the whole region."

The New York State Department of Environmental Conservation is repairing that dam at the Flowedlands that Brewer mentions and in order to do so, has drained the water from the pond. There was no delay or hesitation for today there are no fish. You should know, too, that Lake Colden, Lake Tear-of-the-Clouds, the upper Opalescent River and, in fact, all of the High Peaks ponds are sterile and have no fish. When you climb New York State's highest mountain, Mount Marcy, you cannot catch your dinner of brook trout in a pond along the way as I did as a young man.

The ramifications of acid rain are only just beginning to surface in some respects. I told of the fishery of Big Moose Lake. Last week I spoke with a resort owner on Big Moose Lake and heard one of the most troublesome reports that has yet come to my attention. There was a report one morning of an odd taste in the tap water. He tasted it and had to agree. Since his was a spring water supply, he checked it out immediately and found nothing. He took a faucet sample and sent it to the laboratory. The analysis showed there were high concentrations of copper and lead in the drinking water. He called in a biologist and a chemist and they tested the spring water and found a low pH reading. Further testing has shown that many neighbors and neighboring resorts using both spring water from the lake basin

and Big Moose lake water have the same low pH. What this acidified water is doing is leaching copper from the copper water pipes and lead from the soldered joints into their drinking water. A few days after this incident my friend had trouble with the septic system of his resort. Investigation disclosed that the anerobic bacteria which are the main factor in the proper working of the system were not functioning and the septic system was sterile. My friend tells me the bacteria are especially susceptible to copper and this metal was coming into the system in sufficient volume to kill them and make it non-operative. This problem is also surfacing at other locations. There is no way I can put a dollar value on this. My friend has corrected his problem by filtering his water through crushed limestone at considerable expense. This situation was discovered and corrected but I ask myself is it happening elsewhere and is there any danger to people? And how do you interpret these problems in terms of the economy? Now and in the future?

The other day at the annual meeting of the New York State Conservation Council a friend from Rome, New York, stopped to tell me a story he found quite upsetting. He is an experienced trapper. Incidentally, in New York State trappers have an annual income of more than 12 million dollars and there were some 22,000 trapping licenses sold last year. During the last trapping season, my friend had gone back into an area he had trapped frequently in the past with success. His sets were for weasel, mink, otter, fisher and raccoon. His success was zero. And then the reason dawned on him. This was in an "acid rain disaster area" as the local people call it. There were no fish; therefore, the animals that feed on fish had to leave. How can you put a dollars and cents value on that? The environment will support only so much wildlife. You can't move a population from one area to another populated area and have them all survive so there must be a tragic loss of wildlife numbers and an unmeasurable decline in the quality of life.

At the Syracuse College of Environmental Science and Forestry we have a group of scientists and biologists who are conducting an ongoing research program on the effect of acid rain on plant life and trees. Their findings are not yet conclusive.

But their implications are frightening. The acid in rain and snow scour tree leaves, causing what the scientists call "cuticular" damage which, in turn, greatly increases the tree or plant's susceptibility to disease. Laboratory studies have demonstrated that plants in grounds saturated with acid rain suffer from a lack of nutrition. Research indicates that the acid content of rain and snow leaches nutrients out of the soil and, therefore, they are not available to the growing plants. Certain species of trees may be particularly susceptible to this action. For the Adirondack area, this is a direct attack on our principal year-round industry—the wood products industry. Most of our forest land that is privately-owned is managed in some fashion. Several paper companies have large holdings in the area and have their lands on a sustained yield basis. Most other private landowners periodically cut for lumber, pulp, and firewood on their lands. If the trees are destroyed, the loss would be obvious and would need no explanation from me and this is a real possibility at some time in the future if nothing is done. But perhaps more insidious would be a substantial reduction in the growth rate which might be caused by this nutrient loss. Foresters tell us this is a very real possibility in the near future if the acid rain situation is not corrected.

As a resort owner and as one who lives in the Adirondacks which depends on the resort and recreation industry as its economic base, I am apprehensive. I am sad that governmental regulations permit industries in other parts of our wonderful country to kill fish in my area. I also feel that perhaps the fish are just the indicators of worse things to come. Do we have to wait until the sulfuric and nitric acid in the rain and snow is proven to affect people?

I can't correct this measure--you must. When our forefathers established our Constitution they devised an incomparable formula for living together and they gave the Congress the authority to enforce it and keep it effective. In the suburbs, if my neighbor has a dog that barks all night or a stereo that disturbs the peace, I go to my Town Government and the problem is corrected. To live together we have to consider each other. Where there is a national problem, such as this one,

you--the members of Congress--are the ones we turn to and the ones we expect to correct a bad situation. We know and you know what is causing the acid precipitation and where it originates. It can be corrected—I only hope that you will accept and understand the importance of what is presently happening and what is about to happen and take the necessary steps to stop this environmental degradation before it becomes a national disaster.

September 23, 1980

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FOR IMMEDIATE RELEASE
July 26, 1979

The New York State Adirondack Park Agency today issued a summary report by Commissioner Anne LaBastille describing the growing peril of acid-rain in the Adirondack Mountains. The report details the increasing evidence that acid-rain could be initiating subtle but potentially significant long-term and large scale changes to the wildlife and forest ecology of the Adirondacks as well as creating possible hazards to human health through effects on municipal water supply systems.

On the basis of the report, the Agency resolved to present its concerns to the United States Environmental Protection Agency in conjunction with hearings being conducted on proposals to allow exceptions to air quality standards and regulations for certain industries and utilities in the State of Ohio--the source of much of the pollutants causing acid-rain in the Adirondacks.

In releasing the report, APA Chairman Theodore M. Ruzow said, "The Adirondack Park Agency is calling on all citizens and friends of the Adirondacks to join with us in the battle to prevent the destruction of the Adirondack environment from this insidious threat. We have already received offers of mutual assistance and cooperation from the Adirondack Council and its constituent environmental groups as well as from the Adirondack Park Local Government Review Board. We must all work together on this problem in a way which transcends our individual differences and looks to the future of the region's economy and its environment. I am urging all permanent and seasonal

residents and local governments of the Adirondacks to express their concerns to the President, the Congress of the United States, and the United States Environmental Protection Agency."

The changes in air quality occurring in the Adirondacks were reported as early as 1969 by Vincent J. Shaefer of the Atmospheric Sciences Research Center, State University of New York at Albany, in a report to the Temporary Study Commission on The Future of the Adirondacks. Last year, a conference on acid-rain co-sponsored by the Adirondack Park Agency and the NYS Assembly brought together even more evidence of this problem. Studies since that time have only served to reinforce the concern that acid-rain could prove to be the most serious threat ever to be faced by the Adirondack region.

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REPORT ON ACID PRECIPITATION

By

Anne LaBastille, Ph.D.
Commissioner, A.P.A.

The effects of acid precipitation--both economic and environmental--are rapidly becoming more evident and threatening. The increased usage of fossil fuels and vehicles since the 1950's has led to mounting air pollution with fallout in distinctive patterns. Mountainous forested areas having high rain and snow falls, shallow bedrock, acid soils and waters are prime targets. In the United States and Europe, the Adirondack Mountains of New York State and the southern Scandinavian highlands respectively are hardest hit since the prevailing wind and weather patterns carry air pollution from heavily industrialized regions directly to them, even up to 1,000 miles away. In particular, the Adirondacks are the first high land mass met by west winds from the industrialized Ohio valley and southern Ontario. Resultant precipitation is heaviest on the western slopes and at higher elevations.

Acid precipitation is rain and snow contaminated chiefly with sulfur dioxide and nitrous oxides in the atmosphere which form dilute sulfur and nitric acids in solution. When

acidic rain and snow fall on higher lands and neutral to acidic waters, there is no possibility of buffering or neutralizing them such as might occur under alkaline conditions. Recent research has shown that pH readings (a measure of acidity or alkalinity) in Adirondack waters are in the 4.0 to 5.0 range, with extreme lows of 3.0 to 4.0 during spring run-off and heavy autumn rains. As compared to measurements taken in the 1950's, this is an increase in acidity on an order of 20 times over the "normal" (5.7 pH) of rainwaters. Before the Industrial Revolution, acid precipitation, as we know it today, was probably nonexistent and certainly rare before the 1920's.

These low pH values are producing a number of serious environmental impacts on fisheries, water bodies, wildlife, forests, soils, buildings and human water supplies.

FISHERIES: The most obvious effect has been in the reduction of trout and other species of fish in Adirondack lakes. In a survey of over 200 lakes at higher altitudes in the western Adirondacks, 90 per cent were found to be devoid of fish, and pH readings were under 5.0. A similar study done between 1929 and 1937, showed only 4 per cent of those lakes were fishless. Already a $1.5 million decline in revenues for this recreational industry has occurred. In southern Scandinavia, 75 per cent of the trout and salmon fisheries have been lost. Most fish, especially eggs and

fingerlings, succumb to acid precipitation in the early spring when the thaw carries accumulated acids from winter snows into water bodies. These affect the fishes' gill membranes and respiration. Adult females may experience lowered calcium serum levels during reproduction, which decreases fertility and alters spawning behavior.

WATER BODIES: The normal appearance of a lake or pond turned sterile by acid precipitation is that of extreme clarity tinged with blue. Little aquatic life survives, and fish-eating animals, such as loons, herons, and otter, become scarce. Although most aquatic vegetation, including phytoplankton, is suppressed, there can be blooms of green algae and sphagnum moss. Waterfront real estate values may be adversely affected, especially in tourist regions, and recreational opportunities are impoverished.

FORESTS: Preliminary research in Scandinavia indicates that acid precipitation is reducing tree vitality and causing an overall growth loss of one per cent per year of the normal growth gain in timber. Probably similar findings will soon be forthcoming in the United States both for timber and maple syrup production. It is already well documented that high mortality of trees exist around certain factories and copper smelting plants. There is a new suspicion that acid rain and snow are lowering the resistance of trees to various diseases and blights.

They may also reduce seed germination, damage seedlings, and interfere with photosynthesis. At a time when the energy crisis may direct our attention to wood as a renewable energy source, the forest products industry will suffer substantial economic loss if the rate of growth of trees and their overall health is perennially reduced.

WILDLIFE: Specific research on deer in Poland has shown changes in hormone levels resulting in stunted antler growth and loss of body growth in animals browsing on vegetation contaminated with acid precipitation. The depletion in the aquatic food chain and subsequent effect on piscivorous birds and mammals has already been noted above. Amphibians, such as frogs and salamanders, are also very vulnerable to acidic conditions. These animals form basic links in many food chains and act as important insect controls. The overall cumulative effect of acid precipitation on wildlife is not known at this time, but it may be more serious than research to date can document.

SOILS: Preliminary research shows that acid rain and snow change soil chemistry and may cause a breakdown in the function of micro-organisms in the first few centimeters of topsoil. This can lead to a slowdown in decomposition and recycling of dead organic matter back into soil, and a reduction in nitrogen fixation. The far-reaching effects of decreased soil production

and productivity are disturbing to contemplate since soils are the basis of terrestrial food chains, agricultural crops, and the substrata of forest and pastures.

MUNICIPAL AND PRIVATE WATER SUPPLIES: Initial research in a few Adirondack towns has shown that where ground water impacted by acid rain and snow is allowed to sit in metal water lines, leaching of lead and copper from pipes and solder occurs rapidly. The longer the water stays in the lines, the greater the heavy metal contamination. Pitting and corrosion of metal lines also takes place at an accelerated rate, resulting in increased plumbing problems. Even samples of Adirondack spring water, completely unexposed to metal pipes, have been found to contain copper and lead levels "at or slightly above the recommended safe drinking standards; and also remarkable were the high levels of aluminum." (Fuhs, 1979). These trace metals are being leached out of bedrock and soils by the acid precipitation. To date, no direct threats to human health have been seen; however, acid precipitation can cause violations of safe standards of drinking water. A close watch should be kept on municipal water supplies coming from groundwaters and advisories issued to the public if metal levels rise above safety standards.

BUILDINGS: It has been well documented that acid precipitation accelerates erosion and weathering of metal, painted wood, and many kinds of stone used in buildings, monuments, outdoor

statues, etc. Examples of famous edifices suffering decay are the Parthenon, the Colosseum, and the Taj Mahal.

FUTURE OUTLOOK AND RESPONSIBILITIES: There appears to be no long-term and permanent solution to the acid rain phenomena other than cleaning up the point sources of pollution to the atmosphere in this country and others. Short-term remedies, such as liming lakes to reduce acidity and breeding acid-resistant strains of fish, are mere palliatives. There does exist an adequate and varied technology for dealing with emissions and keeping acid precipitation to a minimum. Cleansing devices should be installed in car and steel factories, fossil fuel and smelting plants, and vehicle emission systems at the earliest date, and costs should not be the limiting factor.

References:

"The Killing Rains" - Anne LaBastille, Ph.D. - GARDENS May 1979

"Death from the Sky" -Anne LaBastille, Ph.D. OUTDOOR LIFE, March 1979

"Effects of Acid Precipitation on Drinking Water in the Adirondacks" Wolfgang Fuhs, Ph.D. - NYS Dept. Health - Technical Memorandum - May 1979

"Scientific Papers from the Public Meeting on Acid Precipitation" - New York State Assembly and Adirondack Park Agency 161 pg. - May 1978

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Resolved, that the Adirondack Park Agency of the State of New York hereby accepts the attached statement of Commissioner Anne LaBastille and directs that the Agency take such action as may be necessary to include the statement in the record of hearings recently conducted by the United States Environmental Protection Agency in Cleveland, Ohio, and, be it further

Resolved, that the Adirondack Park Agency opposes any relaxation of the promulgated air quality standards and regulations designed to minimize sulfur dioxide and nitrous oxide discharges into the airshed of the Adirondack Park, and urges the Environmental Protection Agency to take every possible measure to ensure the installation and utilization of the best available technology to prevent such emissions and thereby reduce or prevent damage to the natural resources of the Adirondack Park through acid precipitation; and, be it further

Resolved, that additional copies of the statement of Commissioner Anne LaBastille be transmitted to the President of the United States, to the Governor of the State of New York, to the Senators and Congressmen representing the state of New York in the U. S. Congress, to the New York State Legislature, to the Administrator of the United States Environmental Protection Agency and to the Commissioner of the Department of Environmental Conservation of the State of New York.

Senator STAFFORD. We will now invite the third member of the panel to speak to us. Mr. Gracie?

STATEMENT OF JAMES W. GRACIE, CHAIRMAN OF RESOURCE MANAGEMENT AND PROTECTION COMMITTEE, TROUT UNLIMITED

Mr. GRACIE. Good morning.

I am here representing Trout Unlimited, which is a nonprofit organization concerned with water quality in our cold water resources. Cold water resources may sound like a funny term, but they are really our trout and salmon resources. They also, coincidentally, happen to be the top of our watersheds. Generally these are the streams which are at higher elevations, have colder temperatures, and are most often in sensitive areas.

The down water streams that we call warm water, which in the East are bass streams and tidal estuaries, are not sensitive. They are generally buffered well enough that they are not going to be immediately impacted by acid precipitation.

My organization has gotten involved in this area of concern because we feel it is the No. 1 single threat to our salmon and our trout resources in the history of this country. We have seen it happen now in high elevation lakes in New York, as has been testified.

We are also seeing it in streams, which was a surprise to us once we began to look into it, in Pennsylvania, West Virginia, and in New York State also. It is generally impacting the first and second order streams, the little tributaries first.

In terms of area, they are not significant. In terms of their importance in the watershed, they are significant. The first, second, and third order streams are generally the areas which we call nursery areas where trout spawn and where they reproduce.

The other unfortunate coincidence in this effect is that the most sensitive life stages of fisheries are the eggs and the fry. They are in the stream in the winter and early spring when the impact is worse. Generally in-stream effects are very serious at times of first and second snowmelts in early spring and late winter.

I realize you asked all witnesses to testify to the economic impact of acid precipitation. That is a very difficult problem. We do not know what the extent is today, much less what the damage is going to be in 10 years if there are no changes.

I did manage to dig up some figures on the economic value of fishing, particularly of cold water fishing. This is from the "1975 U.S. Fish and Wildlife Report." They indicate that cold water fishermen in 1975 spent $2.93 billion. That includes such things as equipment, transportation, food, and lodging.

If the increase in that has been proportional to the increase in license sales, which is about 10 percent a year, then in 1980 when the next 5-year report is completed that figure will be $4.7 billion.

Obviously we are not going to lose all of our cold water resources. Probably when we lose 1 percent of them, we will not see a loss of too many dollars from the total. Maybe if we lose 10 percent, then the opportunities available to fishermen will be impacted on a wide enough scale that we would lose 10 percent of the dollars that are spent on that.

Let's say if we lost 10 percent, that would be $470 million. Those are pretty overwhelming figures to me, $470 million lost of $4.7 billion being spent on essentially trout and salmon fishing.

I am not sure that really describes the impact adequately to a resort owner who depends on something like Big Moose Lake in the Adirondacks. He cannot take his business elsewhere very easily.

If we as fishermen do not have opportunities to fish for trout in our local regions—and it is becoming increasingly more difficult to travel great distances—the impact and loss for people and resort owners in local areas would be total. Everything I see indicates that we are going to see that in some regions.

I cannot substantiate these figures, but I heard a man from EPA make the statement and I have read it in several newspapers since then. We have been told that if all the oil-fired powerplants in the United States were to convert to coal, spending the cost for best available technology, which includes flue-gas desulfurization and combinations of treatments including coal washing, that the conversion could be accomplished with a 95-percent reduction in sulfur oxides at no increased cost over generating power with oil. If that is true, then maybe we had better get on with it and not worry whether it is $2 billion and whether we can substantiate enough benefits from doing it today.

The Congress has authorized—and I think moneys are already committed to the tune of—$40 billion to clean up the Nation's waters. This is just one segment of the 1972 Water Pollution Control Act amendments. This is just the Federal construction grants program which enables municipalities to build sewage treatment facilities.

Forty billion dollars is being spent to clean up water. I do not know what benefit that is going to be if we lose a major portion of it to acid precipitation.

I have submitted a written statement. I hope you will have an opportunity to see that. I welcome any questions.

Senator MITCHELL. All written statements will be included in the record of the hearing.

[The prepared statement of Mr. Gracie follows:]

JIM GRACIE, CHAIRMAN
Resource Management and Protection Committee
3853 Clifmar Road
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STATEMENT OF
JAMES W. GRACIE
CHAIRMAN
RESOURCE MANAGEMENT AND PROTECTION COMMITTEE
TROUT UNLIMITED
BEFORE THE
JOINT SMALL BUSINESS COMMITTEE AND
THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE
SEPTEMBER 23, 1980

Good morning Mr. Chairman and members of the committees. I am James W. Gracie, Chairman of Trout Unlimited's Resource Management and Protection Committee. Trout Unlimited is a non-profit organization whose primary objective is the protection and enhancement of the cold water resources of North America. I welcome the opportunity to meet with you this morning to discuss an extremely serious problem, the impact of acid precipitation on our nations sport fisheries.

Acid precipitation is viewed by the members of my organization as the most serious threat that salmonid fisheries have ever faced. Dr. Carl Schofield has reported that more than half of the high altitude lakes in the Adirondacks had already ceased to support fish by 1975. Ralph Abele, Executive Secretary of the Pennsylvania Fish Commission, has reported that headwater streams in Pennsylvania have already been impacted. The extent is not yet quantified. In West Virginia, we are told that many streams

cannot be stocked in early spring because melting snow acidifies the water enough to cause fish kills.

Acidification is occuring in high elevation lakes in Maine and New Hampshire, from New York to Georgia in streams and lakes throughout the Appalachians and is probably imminent in sensitive areas of northeastern Minnesota, Wisconsin, Michigan and north central Florida. In most cases the effect on fish life has not been documented yet.

In general, the impact on fisheries will not be as dramatic or visible as fish kills in West Virginia. Events like that will be the exception rather than the rule. In a conference which I attended with about six hundred other citizens of the United States and Canada, Dr. Harold Harvey of the University of Toronto, described the more typical responses of fish populations to acidification. Since eggs and young fish are more sensitive to changes in pH than adult fish, the more typical result is reproductive failure. This is observed in the final stages as a population of a few larger, older fish and no young. Trout are particularly vulnerable to acidification because eggs hatch in late winter or early spring, a time when melting snow can cause the most rapid changes in pH in streams. Thus the most vulnerable life stages must face the worst conditions.

A real tragedy may already be developing in the case of the Atlantic Salmon. This once abundant game fish had almost disappeared from our waters only a decade ago. Massive restoration efforts including clean-ups and the installation of fish passage-ways in rivers in the northeastern United States as well as restrictions on high seas fishing have started this noble fish on the road to recovery. The gains expected from this effort could be completely eliminated by acid precipitation since, as in

the case of trout, the most sensitive life stages are instream when the worst conditions occur.

In attempting to assess the economic impact of acid precipitation on sport fishing we have several difficulties. First of all we do not know what the total loss will be, only that it will be widespread throughout the eastern United States, the northern mid-western states and the Northwest. Some streams and lakes will not be affected in the near future since they drain areas with extensive deposits of limestone which can neutralize heavy concentrations of acid for the foreseeable future.

Second, we are just beginning to document the impact in many areas, so it would be presumptuous to predict the ultimate extent of fisheries losses.

For these reasons, I will state the assumptions in my estimates of economic impact:

1. Dollar values for fishing are taken from the 1975 National Survey of Hunting, Fishing and Wildlife-Associated Recreation of the Department of the Interior, US Fish and Wildlife Service.
2. Calculations will be based on cold water fishing, since cold water resources will be the first to be affected.
3. Lost opportunities for cold water fishing will be considered full value per trip, even though this is not completely accurate since the figure per trip assumes a portion of the annual equipment costs. Thus, as long as fishermen perceive that they have other opportunities to fish for cold water species they will continue to purchase equipment.

The U.S. Fish and Wildlife Report gives the following facts about sport fishing:

53.9 Million Americans fished in 1975.

They participated in 1.3 billion days for an average of 24.5 days per angler in 1975.

They spent 15.2 billion dollars or $282 per angler ($11.50 per day).

•18.4 million participated in 235.3 million days of cold water angling.

•6.7 million participated in 60.9 million days of sea run angling.

•Cold water and sea run angling would be most heavily impacted by acid precipitation. It is further reported that cold water and sea run anglers spent a total of 3.99 billion dollars for items such as equipment, food, lodging, transportation and fees exclusive of licenses. Of course, we will not lose all of our cold water resources or our anadromous fishery resources. Actual losses to-date are only a fraction of the total where they have been measured. Some local regions may be impacted totally, but a one hundred-mile trip to a stream or lake with high buffering capacity may provide an alternative fishing opportunity.

The United States Environmental Protection Agency is currently attempting to estimate the economic impact on sport fishing as well as the other areas that will be affected such as damage to buildings, statues, human health, forest production and agriculture.

Trout Unlimited has begun a major effort to educate its members and the general public of the potential impacts of acid precipitation. We are distributing an excellent slide show prepared by the Friends of the Boundary Waters which documents what is currently known about acid precipitation. In addition, we are seeking funding from several sources to support a

volunteer monitoring effort to study the instream effects of acid precipitation is approximately twelve trout streams in the eastern United States.

We are concerned because current trends indicate that the situation will get worse before it gets better. We hope that current concerns over energy costs do not lead to short-sighted decisions which could have irreversible impacts.

This concludes my prepared statement. I will be happy to respond to any questions you may have.

Senator MITCHELL. Not having been here during your presentations, I have no questions of you gentlemen. Thank you very much for your willingness to appear here today. I assure you, as I indicated earlier, that everything you say will be included as part of the record which will serve, hopefully, as the basis for beginning of action to correct the problem we are discussing today.

Thank you very much.

Mr. ALWARD. Thank you for giving us the opportunity to be here.

Senator MITCHELL. The next witness is Dr. Orie Loucks, Science Director of the Institute of Ecology, Indianapolis, Ind.

Doctor, we would be very pleased to hear a summary of your statement. If you have a written statement, we would be glad to include it in its entirety in the record of this hearing.

STATEMENT OF DR. ORIE L. LOUCKS, SCIENCE DIRECTOR, THE INSTITUTE OF ECOLOGY, INDIANAPOLIS, IND.

Dr. LOUCKS. I have provided a written statement. I will try to summarize from it as quickly as I can.

I have worked in the field of forestry for some 30 years and on environmental toxicants for the past 15 years.

In this testimony today I want to consider three aspects of acid rain impacts on crops, forests, and fisheries which expand on some of the testimony on economics which you have already heard.

First of all, there are two main classes of effects from acid rain and related atmospheric deposition. These are, first of all, the seasonal effects that reduce yield, and then, second, the irreversible effects on resources that may extend over several decades.

The second aspect of the testimony I want to address has to do with the time span over which effects on income and wealth are expressed when we deal with resources as different as crops, forests, and fisheries.

As a bottom line I will provide a preliminary estimate of the total magnitude of consequences of two types of atmospheric deposition, oxidants and acid rain, that were invited in the letter from the committee.

There have been several reviews on acid rain and its effects, particularly the Senate Environment Committee hearings on acid rain. I do not want to duplicate that.

Let me address, first of all, the class of short-term income effects that are induced on crops and forests each year and from which, as far as we can tell, there are no irreparable damages remaining if the exposure is terminated.

These effects are especially important on foliage and root crops where the damage, in addition to affecting yields, is important for the market value of root crops, making them relatively more uneconomic from regions of high atmospheric acid input in comparison to the same crops grown in regions of lower acid input.

These effects could be serious for individual farmers, but have a very modest effect on a regional economy. In addition, there could be recovery if we knew how to terminate acid rain within a matter of a few years.

There is a second range of effects that have to do with intermediate time spans of a decade or so.

Senator MITCHELL. Let me interrupt you and ask you about the first aspect.

You are suggesting that there is a reduced crop yield in certain areas based upon acid rain deposition in those areas?

Dr. LOUCKS. On foliage and root crops.

Senator MITCHELL. Does that express itself in a reduced production per acre or some other method of measurement?

Dr. LOUCKS. It is expressed in reduced income per acre. These results at this time are largely from experimental studies, but the studies have been carried out with simulated acid rain that reproduces rain at concentrations now being observed in the Northeast.

Let me observe, too, that the most acid precipitation data that I have seen is from Riverside, Calif., where we do have an abundance of crops of the kind that are affected by acid deposition.

Senator MITCHELL. I was just trying to understand. How are they affected? Do you get a smaller product? Do you get a greater spoilage? Do you get less quantity per acre? Is there any pattern to the manner in which it is manifested?

Dr. LOUCKS. On crops like spinach and lettuce you get lesions on the surface of the foliage which make it less desirable in appearance for marketing. In the case of radishes you get lesions on the surface of the root crown, which of course is the marketable product. These lesions also affect market quality.

Senator MITCHELL. In those respects it is a cosmetic effect?

Dr. LOUCKS. That is right, but an income effect.

Senator MITCHELL. It has an income effect. However, there is nothing wrong with eating that lettuce or that radish. People do not like to buy them obviously if they have some lesions on them.

Dr. LOUCKS. We have not examined fully the metal uptake question of these vegetables, but we do not believe there is anything wrong with the health quality of them at this time.

Senator MITCHELL. Thank you, Dr. Loucks.

Dr. LOUCKS. The middle range income and wealth effects are those that are expressed over a period of a decade or so and are more likely associated with the mobilization of toxic elements in the soil as a result of the addition of hydrogen ions—acidity—to the surface. The elements that are so mobilized are aluminum, particularly, but also iron and some of the metals such as arsenic and cadmium.

Certainly, we have not yet done sufficient surveys to determine the extent to which these mobilized elements are being picked up by crops in certain acid regions. We doubt that it is a very serious

problem in the United States, but it appears to be a potentially serious problem in Canada.

Associated with this midterm effect are the effects that we observe as a gradual collapse of stream and lake fisheries over the period of a decade that results both from the mobilized toxic elements and from the hydrogen ion addition.

May I observe here, too, that one of the types of effects that one can call an immediate short-term effect is that part of fish kills being observed as a result of rapid aluminum mobilization flushing into the lake, fish kills that take place in as little as 2 or 3 hours, but which may not be repeated again for several years. The population can recover.

That effect has to be distinguished from what I am calling the midrange effects where annual additions of hydrogen ions and aluminum gradually deplete the fish population over a decade, an effect which we believe would show recovery if abatement were accomplished within another decade.

Let me turn now to the class of long-range wealth effects that are expressed over periods of more than two decades, and which affect property values as well as certain aspects of resource systems that appear to be irreversible.

Irreversible effects here concern questions such as the loss of nutrient stock from soils—in relation to forest productivity—and chemical alterations of ground water. Although we are much concerned about this question of irreversibility, nearly all environmental modifications introduced by man are reversible in geological time. Therefore, we have to define what we mean by an irreversible effect.

For the purposes of my testimony, Senator, I am asking that we agree that economic effects that are produced by one generation but which are borne as a cost by the next generation—in other words, there has been no recovery and another generation is bearing this cost—should be viewed as irreversible. I will be addressing the cost aspects of those kinds of income and wealth redistributions by the time I conclude my remarks.

One type of irreversible effect, then, is the depletion of calcium and magnesium from the soil profile on coarse-textured soils. These are mostly forest soils.

Our studies in central Wisconsin show that calcium and magnesium depletion of the magnitude we are seeing—from European and Canadian research—could be expected to produce growth reductions of 10 to 20 percent on the most sensitive soils, not on all soils, but on the most sensitive soils, over 20 to 30 years. In other words, it is not an effect that we will see immediately, but it is an effect imposed on future generations by the continuation of the present energy production practices we have.

Senator MITCHELL. Dr. Loucks, in his testimony earlier this morning Dr. Norton suggested, if I understood him correctly, that there may be a short-term increase in forest productivity due to acid rain and that the long-term effect is impossible to gage at this time.

Do I understand your testimony to be a little bit different from that?

Dr. LOUCKS. No, I support his testimony completely. I was telescoping my remarks. Let me amplify them.

Indeed, there is a relatively large quantity of nitrogen in acid deposition which can be stimulatory to first production in the short run. However, plant and forest growth requires a broad spectrum of nutrients, of which nitrogen is only one. It also requires calcium, magnesium, and other cations. These cations are depleted from soil profiles over long periods.

Thus, the response that we expect to see, and which has been seen in Norway, is a period of perhaps 10 to 15 years or more of benefit, depending on rate of acid inputs. However, by that time it may not matter how much more nitrogen you add. If there is not sufficient calcium and magnesium in the soil, or you have generated sufficient aluminum toxicity a very toxic element to a wide range of plants and animals—then in the second and third decades of acid treatment we expect to see a decline in forest growth.

Senator MITCHELL. You say "we expect to see." Does that mean nobody has seen that yet?

Dr. LOUCKS. In experiments in Norway where acidification is being applied under controlled conditions, they are seeing the kind of decline I have described, and for the reasons that I have outlined, within 6 years of the initiation of the experiment, but that is at a higher acid input than we are currently observing in nature. We believe that is credible supporting evidence of the response we anticipate based on mass balance and theoretical reasons, which is what I described.

Let me go on and address the question of the effects of other sorts of atmospheric deposition. I am specifically referring now to oxidants which are formed by the same emissions and by the same general chemical reactions as those producing acid rain, and which are part of the atmospheric deposition problems which the committee invited testimony on.

As part of our work on the Ohio River Basin energy study during the past 2 years we had an opportunity to consider in detail what is the magnitude of effects on crops and forests in the Ohio Valley region from the presently observed oxidant levels in that area. We were asked to relate that to the precursors of oxidants—that is, the energy combustion process and, in particular, the prospective doubling or quadrupling of coal-fired energy utility generating capacity in the region.

The result of these studies—filed in my detailed report—indicates that at the present time, or rather in 1976, we were experiencing in the Ohio Valley 8 percent crop losses of corn, 14 percent reduction in yield in soybeans, and 6 percent reduction in yields in wheat.

These data are largely based on greenhouse and field experiments extrapolated by an interpolative procedure, but they have been corroborated by summaries of all the experiments in which air was cleaned and passed over these crops throughout the eastern United States. Here we now have an average yield improvement of 12 percent when clean air is used over chambers in the field.

What are the economic implications of yields of this magnitude, not only for individual farm operators but for smaller businesses,

such as feed and fertilizer businesses and equipment dealers, in the Ohio Valley and for the national economy?

Monitorization of these crop reductions was undertaken by Dr. Walter Page of West Virginia University as part of the ORBES study. He expresses these costs—that is, the consequences of crop reductions—as a prospective benefit to the region if the crops could be grown under clean air. He chooses to accumulate the benefit and the total crop production in clean air to the year 2000, in order to get a value that would be more comparable to the investment cost of abatement.

These estimates lead to conclusions that there is $8.1 billion of prospective benefit from yield improvement, capitalized from now to the year 2000, using a 10-percent discount on future yields. That is 11.9 percent of the total prospective agricultural production of the region.

To date, there have been no explicit similar calculations for the value of oxidant effects on forests of the Ohio Valley, but we have estimated the current reduction in forest growth for this region is about 5 percent of the annual productivity. It is difficult to put a dollar value on it because of the very small field value of wood and our inability to monetarize the multiplier effects of wood.

Senator MITCHELL. Let me see if I understand this correctly. Your testimony is that one study conducted by Dr. Page estimated a loss in crop yield in one specific area of the country, the Ohio River Basin, for the period between now and the end of the century at $8.1 billion?

Dr. LOUCKS. Yes, the estimate of crop losses was provided by our institute and our estimate of the national literature. As I say, they have been corroborated by independent experimental work. Dr. Page applied the standard econometric methodologies to that crop loss estimate.

Senator MITCHELL. Is this in an area of unusually high acid rain deposition in relation to other areas such as New England or the Wisconsin-Minnesota-Michigan area?

Dr. LOUCKS. These effects are due to oxidants which are one part of the atmospheric deposition problem and are closely related to acid rain. Oxidants tend to affect the above-ground portions more than the low-ground system. Acid rain tends to affect the below-ground system, that is, soils, ground water, and fisheries.

I think we have to take both into consideration. They have the same precursors. They involve the same chemical reactions. Abatement will be accomplished by the same legislative or regulatory approaches.

Let me answer your question more fully by going on.

What is the bottom line then for the Nation with respect to oxidant effects? If one were to make an estimate today, one could extrapolate from the present studies to areas of similar size and with similar oxidant concentrations. Thus, for the area of New York and the rest of the area in the Northeast north of the North Carolina line one can project losses of about the same size, that is, oxidant concentrations and total crop acreages are such that they would be equivalent to those in the Ohio area.

For another area that would include the upper Great Lakes and the State of Iowa, one could project a similar crop loss, that is, the oxidant concentrations and crops are similar.

When we add the Southeastern States, which are heavily affected by oxidants, as is the south central region as far west as central Texas, and the California and Arizona areas, one has to conclude that the present cumulative value to the year 2000 of oxidant-induced losses approaches $50 billion, expressed in 1975 dollars.

Now, I would like to make a similar calculation with respect to acid rain effects in the areas influenced by that part of the atmospheric deposition picture. In doing so I want to look at the question of how one considers the consequences of U.S. pollutants in Canada.

First of all, it is clear that there is a net transport to Canada substantially in excess of the transport from Canada to the United States.

Senator MITCHELL. The estimate given to us last week at a meeting that we had with several Canadians is about 4 to 1. Does that sound about right to you?

Dr. LOUCKS. That is higher than I thought. It is higher than the numbers I have seen, but yours is undoubtedly more recent testimony.

Senator MITCHELL. I would not assume that.

Dr. LOUCKS. Secondly, I would like to observe that in dealing with effects in another country we have to apply the legal criterion that would apply in a litigation proceeding; that is, with serious, permanent, and irreparable damage in the foreign country, damages such as could possibly be claimed in a litigation.

Therefore, let us consider the area within Canada in which there appears to be serious, permanent, and irreparable damage and include that part of the Canadian losses, as part of the U.S. calculation. But within the United States we should include annual losses whether these are to fisheries, crops, or forests.

To begin with, let us note that the per-acre cost in the Ohio Valley region due to oxidants came out to about $70 on a per-acre basis, cumulatively through the year 2000.

For several reasons which are in my testimony, it appears that one can use that number, or a number close to it, as an expression of the cumulative value of benefits from acid rain abatement over the sensitive portion of the region. This relates to the crop damages I have noted—an annual effect at least in the United States—effects on forest growth, effects on at least some soils, fishery losses, long-term decline in property values of acidified lakes, and effects on the recreational industry. These, taken together, appear likely to be in the range of $50 to $100 per acre for the sensitive regions.

Please note that this estimate is very close to the cost of abatement by lime application, if that were undertaken on both land and water systems.

Thus, for an area of the Northeast and adjacent Canada, where we are dealing with serious, permanent, and irreparable costs, it appears that we are talking about a $6 to $12 billion present discounted value of acid rain effects, using indirect estimation tech-

niques. I think this estimate stands very close, however, to the estimate that Dr. Crocker gave you a little earlier.

One can also consider the consequences of acidification in the Great Smokies National Park, the Shenandoah National Park, and Wisconsin, Minnesota, and northern Michigan, the high altitude area of Colorado which is currently receiving serious acid additions, and the Sierras of California, and conclude that a similar total cost is being expressed in those regions.

Thus, combining the total of effects from atmospheric deposition of oxidants on crops, and acid rain on crops and fisheries, it appears that the total costs to the country are in the range of $65 to $75 billion, expressed as a cumulative total of potential benefits from now to the year 2000 for effective abatement.

Senator MITCHELL. This is in addition to the amount you described earlier attributable to oxidants?

Dr. LOUCKS. No, sir. The oxidant portion was $50 billion. The total for acid rain would be in the order of $15 to $25 billion.

Senator MITCHELL. It is an aggregate total?

Dr. LOUCKS. Yes.

Senator MITCHELL. $65 to $75 billion dollars over a period of two decades that you estimate.

Dr. LOUCKS. Yes, sir.

Senator MITCHELL. Do you think that is a reasonable estimate, recognizing the many variables and speculative nature of what you are doing?

Dr. LOUCKS. Yes. It is consistent, first of all, with the oxidant estimates that were available 6 to 8 years ago when oxidant concentrations in rural areas were much lower than they are today; that is, they now have higher values. Prices are higher. The estimate we have today is in line with estimates that began to be available as much as 10 years ago.

In the case of the acid rain portion, I think this value is rather similar to the estimate provided by Dr. Crocker. I am considering a larger area than he considered, however. I am including current benefits that would accrue in the mountain regions of the West, where we are now seeing acidification take place, but he has included effects on materials.

Senator MITCHELL. One of the particular problems, Dr. Loucks, is that it seems in the area of environmental damage everybody has their own figures. I have spent most of my career in a courtroom where there is a tendency to reduce conflicting positions to objective facts. It seems very hard to arrive at any objective facts in dealing with environmental consequences.

I am rather confident that the first time I get up and use your figure of $65 to $75 billion, someone who does not share the point of view you have expressed here is going to laugh at it as a ridiculous figure. Therefore, I am trying to get at the degree of confidence that you have in that estimate as a reasonable estimate, understanding and accepting all of the speculative nature of what goes into it.

Dr. LOUCKS. I find them consistent with other estimates that are becoming available.

Second, let me emphasize the aspect of Dr. Crocker's testimony to the effect that, if effects on the most heavily acidified areas are

not recoverable, if they are indeed irreversible, then there are no benefits there from a mitigation strategy. Thus, if the effects are significantly irreversible, this estimate of benefits is unduly high, because they cannot be accomplished.

This, I think, is the principle and the problem with which we are dealing that makes the valuation of economic consequences most difficult and the reason why you are going to get several different estimates.

Another dimension, of course, is how do you valuate consequences beyond the year 2000. We are dealing with forest growth effects and ground water toxicity in that period that are very difficult to quantify now.

That concludes my testimony.

Senator MITCHELL. Thank you very much, Dr. Loucks.

[The prepared statement of Dr. Loucks follows:]

STATEMENT BY
DR. ORIE L. LOUCKS, SCIENCE DIRECTOR, THE INSTITUTE OF ECOLOGY
4600 SUNSET AVENUE, INDIANAPOLIS, INDIANA 46208
BEFORE SENATE SMALL BUSINESS COMMITTEE AND
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
SEPTEMBER 23, 1980

My name is Orie L. Loucks, Science Director of The Institute of Ecology, Indianapolis, Indiana, and for 16 years previously Professor of Botany, Forestry and Environmental Studies at the University of Wisconsin. I have worked in the field of Forestry for some 30 years, and on environmental toxicants effects and societal implications of resource deterioration for much of the past 15 years. As Science Director for The Institute of Ecology, a national consortium of universities, I lead a number of inter-institutional studies of environmental problems covering large areas of the U.S. and Canada. These studies include work on acid rain and air pollution problems supported by several federal agencies and private foundations.

In this testimony I want to address three sets of acid rain impact problems which I believe complement and support the more specific testimony on economics you are hearing. These are:

(1) The classes of acid rain induced effects on natural resources that have monetary significance;

(2) The time spans over which economic effects are expressed; and

(3) The range of effects that have economic significance primarily because they are irreversible.

In line with the Joint Committee's request, I also want to consider other components of atmospheric deposition that are not acidic--primarily oxidants, including ozone (O_3). These also produce income and wealth effects needing consideration as part of the forestry and agricultural impact of atmospheric

deposition. Finally, I will provide a preliminary estimate of the magnitude of the economic consequences of both oxidants and acidic deposition in the northeast and midwestern states.

The Time Frames of Acidic Deposition

Several reviews have been written on acid rain and its effects. I know that the Senate Environment Committee has taken testimony on many aspects of the problem, including apparent sources, transport, and ultimate impacts. I do not want to repeat that material here, except in outline, so that you can see the broad effects picture and begin to distinguish between several major aspects of their consequences for society:

(1) Short-term income effects--those induced in crops and forests annually, with no irreparable damages remaining once the exposure is stopped;

(2) Intermediate-range income and wealth effects--those induced in a decade or so and from which recovery may take place in an additional decade or two (e.g., effects on fisheries); and

(3) Long-range wealth (asset) effects--those which become expressed over periods of more than two decades, and which tend to be irreversible.

The irreversible effects here concern such questions as loss of nutrient stock in shallow or sandy forest soils, long-term decreases in forest productivity (timber yields), and chemical alterations of groundwater. The value implications of these long-term processes are quite different from direct effects on crops or forests that may largely be seasonal.

To assist in understanding these distinctions, I want to cite the relationships shown in Figure 1. Despite some continuing scientific disagreements on details of the chemical transformation of emissions in the atmosphere, and the processing of these acidic materials in forest and crop systems, there is

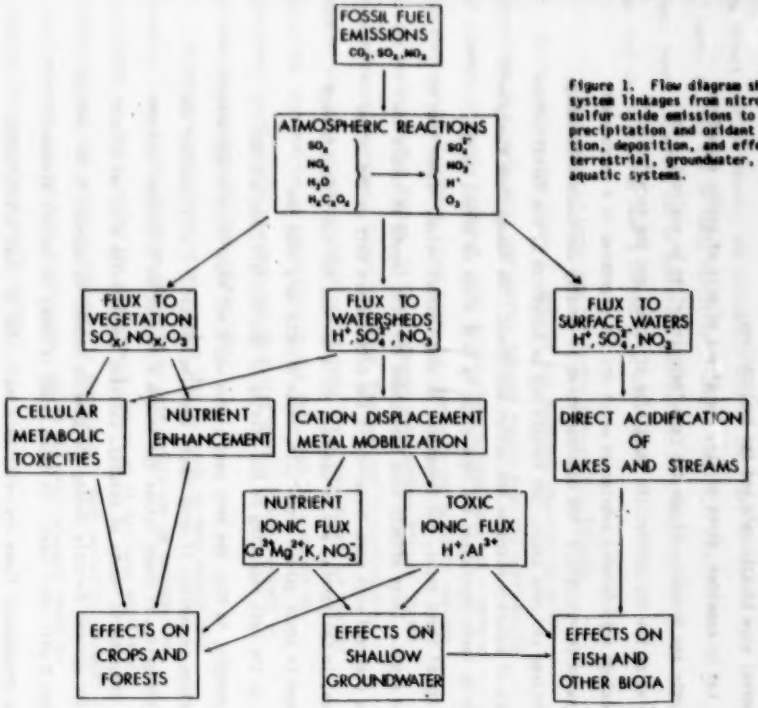

Figure 1. Flow diagram showing system linkages from nitrogen and sulfur oxide emissions to acid precipitation and oxidant formation, deposition, and effects on terrestrial, groundwater, and aquatic systems.

now sufficient general consensus about acid deposition and its effects to present the response relationships shown here as the preponderant but not universal view of acid rain and its implications.

Let us consider, first of all, the direct effects of acidic deposition on crops and forests. (I use the term "deposition" to be explicitly inclusive of the dry particulate deposition of acids, and the term "acidic" to include acid-forming substances which are not expressed in a measurement of low pH in rainfall.) The combined forms of acidity can cause mild damage to foliage and root crops, but forests may be benefited by the fertilization effect of moderate nitrogen and sulfur additions. The damage from atmospheric acids to leafy vegetables and root crops is more often an effect on the quality of these crops, and therefore, on their market value, rather than on yield alone. These effects have been shown for acid inputs at levels now being observed with some frequency in the northeastern part of the United States, in California, and in Canada. While serious for individual farmers engaged in truck garden production, these effects vary from one year to the next depending on the acidity of the rainfall, and are not irreparable, in that the next year's crop would not experience an appreciable reduction in quality if acid inputs could be reduced. I will consider the quantification of these losses for income distribution in a later section.

Atmospheric inputs of acidity, sulfates and nitrates also can affect aquatic systems directly during the growing season, as opposed to the delayed effects I will cover next. In lakes, such as those in central Wisconsin where groundwater flows are relatively small (due to lower precipitation and high evaporation), and where the buffering capacity of the lake is very low, the direct addition of acid appears to be an important part of the

within-season acidification process. These lakes are almost the equivalent of large, sterilized petri-dishes in equilibrium with atmospheric acidity. The direct effects, however, are noticeable only on the algae during the year of input, as they are on leafy agricultural crops. Indirect effects from these inputs, however, can be expressed cumulatively as a modification of the food chain in lakes over a period of several years.

Significance of Long-Term and Partly Irreversible Effects

As is evident from Figure 1, many of the responses incurred by acidic deposition in forests soils and aquatic systems result from the mobilization of elements in poorly buffered, acid soils--elements that were not a part of the atmospheric deposition. Such soils are common in the mountain regions of the western United States, in the southeast and northern tier of states from Minnesota to Maine. Except in Canada, few are used in agriculture. Much of the toxic elemental mobilization takes place immediately or shortly after the introduction of the acidity to the soil, and the elements so liberated, particularly aluminum, may be picked up into surface waters or allowed to seep into shallow groundwaters.

Aluminum is well-known as an element that is toxic to many plants and animals. Some of the aluminum mobilized by acid inputs can be transported to streams and lakes during the same growing season as it has been mobilized, producing fish-kill within a few hours in some lakes. Such mortality produces a local economic loss of some significance, but if the toxic element could be reduced, the populations would recover.

At the same time, some of the aluminum mobilized by acid rain can enter the groundwater and not emerge to influence biological parts of the resource until it reaches springs, streams or lakes as part of the base flow of water

to these systems. Thus, the effects of the toxic elements also must be considered as a continuing input over many growing seasons. This continuous impact on the biology of an aquatic resource over a period of decades produces a more permanent loss of a fishery, as has been observed in Canada and New York state, although long periods of surface inputs produce the same effects. It is important to recognize that these effects can come from modifying groundwater systems, a relatively irreversible effect I shall elaborate on shortly.

Although we are much interested in the implications of irreversible effects, nearly all long-term modifications of the environment by human activity ultimately appear to be reversible in geological time, i.e., over several centuries or a millenium. However, for the purposes of considering an "irreversible effect" of economic significance, the "non-reversibility" of a resource impact may alter income flows in a much shorter period. Let us agree, therefore, that economic effects produced by one generation, but which are borne as a cost by the next generation are of special importance. In effect, we might agree that an effect is reasonably reversible if the response can be borne by the same generation as produced the cause and experienced the benefit. Thus, in further examining the economic implications of long-term effects induced by acid rain, I am defining "irreversible" as being any effect that persists more than twenty years, i.e., emerges as a cost on another generation after benefits to our generation have been captured.

Referring again to the relationships in Figure 1, recent studies in Canada and Europe have shown also that the displacement of calcium and magnesium from unmanaged forest soils by acid rain is an effect of much consequence to long-term forest productivity. Fertilizer treatments and lime

additions maintain agricultural soils in a good balance with relatively little added cost to farmers due to atmospheric acid inputs. Effects of cation stripping on shallow, rocky, and poorly buffered forest soils appear to be very modest over the period of a decade, but are likely to be significant over intervals of a generation or two. Since these nutrients ordinarily cycle continuously in a forest ecosystem, it appears unlikely that a balance can be restored to the annual mobilization rates by the simple addition of calcium sprayed over the forest land from airplanes. (An important difference is evident here from agricultural systems, whose plants grow entirely in a single crop year. The reduced soil nutrient stock tends to produce lower levels of cations in the accumulated organic mass, thus preventing a rapid adjustment of the system through any single application of cation nutrients.) The importance of the loss of calcium, magnesium and other cations rests on their well-documented importance for annual growth of forests. Although the data base is meagre on the magnitude of cation stripping by acid rain, studies in Canada, Europe and Wisconsin suggest reductions in productivity of as much as 10 to 20 percent may be experienced after 30 years of heavy acid inputs on the most sensitive soils. This effect must be regarded as irreversible in the above definition because normal soil leaching processes will tend to remove part of the new geologically weathered cations, and external applications cannot be incorporated quickly into all parts of the system.

In addition, a portion of the annual water budget of forest systems penetrates through the soil profile and enters the groundwater. This groundwater, as we have seen, is chemically altered, and frequently experiences a long lag-time before it emerges as spring flow, or as base flow to streams

and lakes. Several studies in both the United States and Sweden have established that the groundwater of heavily acidified regions is showing elevated levels of both aluminum and iron. In regions of high natural background levels of arsenic and other heavy metals, these elements also are likely to be carried into the groundwater. What is also important is that the elevated iron in these waters can, in turn, substitute for other elements during passage of water supplies to human use (especially in copper piping) and thus introduce significantly altered water quality characteristics in rural and summer residence areas. The displacement of copper from copper plumbing, and the exposure of homeowners to very elevated levels of copper in drinking water is well documented now for New York and Sweden.

While these effects are complex and very difficult to quantify, my principal goal is to observe that costs being externalized in present energy use practices will be borne in large part by future generations, rather than the generation producing the acidic deposition and enjoying the benefits of the cheap energy.

Significance of Synergistic Effects from Oxidants and Acidic Deposition

As the Committee's invitation indicated, there are important constituents in atmospheric deposition other than acidity. One of the key new questions of the past year relates to the potential interaction between oxidants, primarily ozone (O_3) (produced when fossil fuel combustion products react in the atmosphere with sunlight), and the acidic deposition created by the same emissions. Specifically, many crop and forest species are severely weakened by elevated levels of O_3, a response which, in turn, increases the sensitivity of crops and forests to the acidity itself and to the toxic elements mobilizing it. Several crop and forest species have been

shown to be sensitive to aluminum concentrations at the levels being induced from the elevated acid inputs. There is every reason to believe the toxic effects of these elements will be expressed more strongly on plants already weakened by oxidants. Thus, estimation of the costs incurred by acid rain require consideration of atmospheric constituents which may further stimulate the response.

Significance of Oxidant Impacts Alone

In addition to the role of ozone and other oxidants as factors operating synergistically with acid rain, it is important to determine the direct effects on natural resource systems of these components of atmospheric deposition. Ozone and related oxidizing particulates enter resource systems by atmospheric deposition, most often as gaseous uptake by living plants. What makes consideration of oxidant effects particularly important are the effects on aboveground systems, that is forests, crops and home materials such as painting, clothes and wallpaper. In comparison, acid deposition has only a modest effect on forest and crop systems and is more serious for soils, groundwater, and fisheries.

In the course of work by The Institute of Ecology on the Ohio River Basin Energy Study (ORBES) during the past three years, we explored in detail the present effects of coal-fired utility emissions and their transformation products on the crops and forests in this region. In addition, the study was asked to examine future trends in effects, given certain assumptions about the levels of energy development in the region and about prospective compliance with Clear Air Act regulations. Figure 2 shows the portions of a six-state area covered by the study.

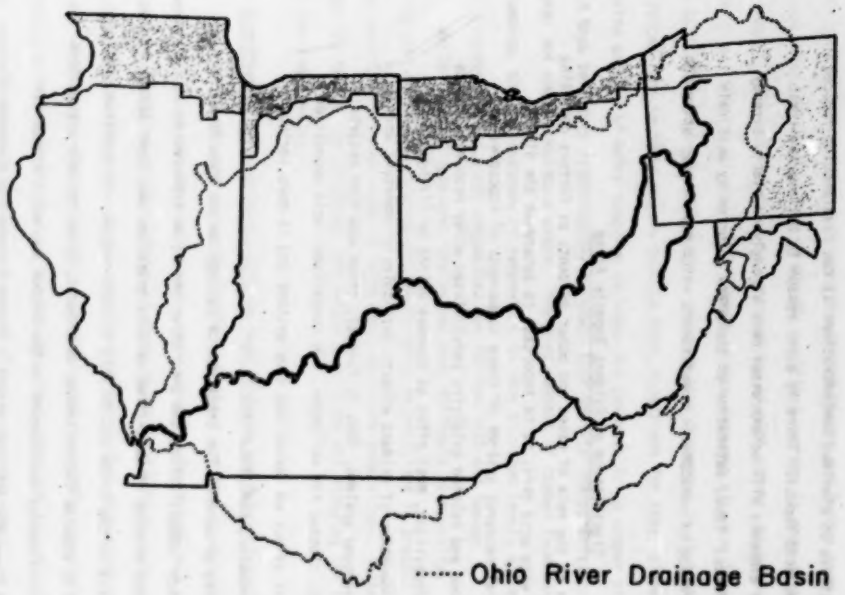

Figure 2. Ohio River Basin Energy Study Region. Phase II

One of the results of this study is shown in Figure 3, illustrating the trends in prospective utility sector emissions of nitrogen and sulfur oxides, (the precursors of acid rain and ozone) for the period from now to the end of the century. It is evident here that sulfur oxides seem likely to be reduced somewhat (depending on the timing of present utility retirements), but nitrogen oxides will increase unless new technology is adopted in the utility industry. On balance, therefore, the total precursors of acid rain seem likely to trend downward only slightly by the year 2000. For reasons associated with the increased NO_x production, the concentrations of oxidants, which affect crops and forests primarily, seem likely to increase significantly.

Let us now consider the consequences of these emissions (and their transformation products) for agricultural yields in this region. In Table 1 are summarized the "crop-loss coefficients" presently operating on agricultural lands in the Ohio Valley Region, as best we can determine them. These indicate that for corn, soybeans and wheat, the probable annual yield reductions during 1976 were 8%, 14% and 6%, respectively. These estimates have been verified by experimental work carried out in many other eastern states during the last two years, and are in agreement with earlier studies of the trends in ozone losses published 6 to 10 years ago. Also in Table 1, are projected crop-loss coefficients for the years 1985 and the year 2000, given the best available estimators of the apparent trends in all NO_x emissions (and associated ozone concentrations) for the eastern United States. In using these estimates it is important to respect the upper and lower bounds shown, for we believe actual values lie somewhere between these limits, rather than at the single value that we regard as most probable. Table 2 summarizes the total estimated crop reductions for the ORBES region, based on the above crop loss coefficients, but expressed now in bushels.

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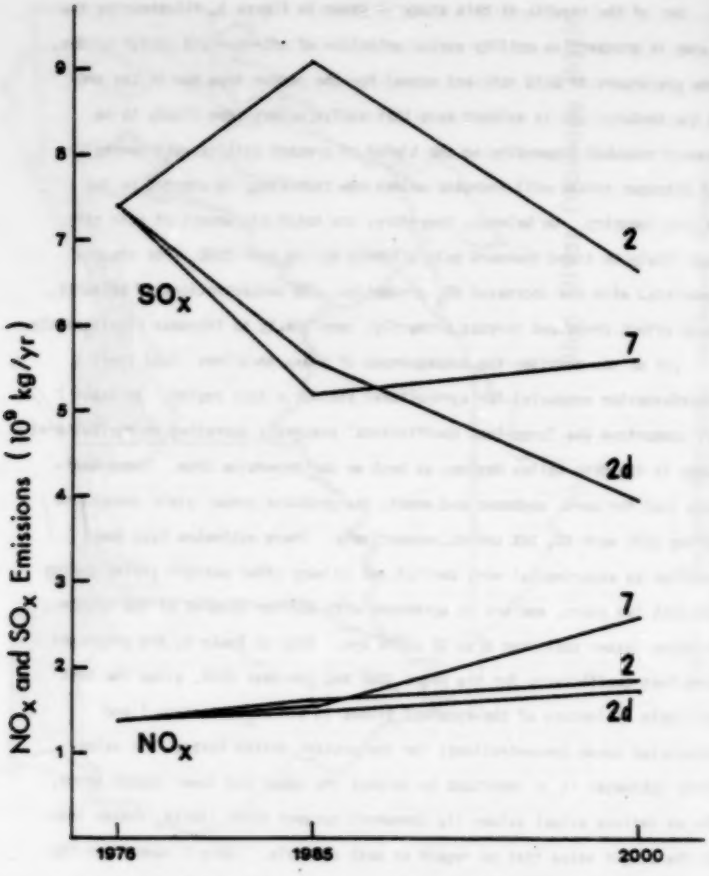

Figure 3. Projections of NO_x and SO_x emissions (1976-2000) under three scenarios of utility development in the Ohio River Basin: Scenario 2 assumes a doubling of electricity generating capacity and non-compliance with State Implementation Plans (SIPs) by 1985; Scenario 2d is the same but assumes compliance with SIPs; Scenario 7 assumes a high growth in the rate of electricity generation by 2000 and compliance with SIPs.

TABLE 1. CROP LOSS FUNCTIONS FOR OZONE EFFECTS ON THREE SPECIES IN THE OHIO RIVER BASIN.

Crop	1976 (%)	1985 (All 3 Scenarios) (%)	2000 Scenario 7 (%)	2000 Scenarios 2 & 2d (%)
Corn				
Upper bound	15	18	19	11
Lower bound	4	7	9	4
Probable	8	11	12	6
Soybeans				
Upper bound	26	41	47	20
Lower bound	5	24	30	2
Probable	14	28	34	7
Wheat				
Upper bound	10	18	23	8
Lower bound	3	5	7	2
Probable	6	13	14	3

a (2) - Scenario assuming compliance with SIPs by 1985 and doubling of generating capacity by 2000.

b (2d) - Scenario assuming no compliance with SIPs and doubling of generating capacity by 2000.

c (7) - Scenario assuming compliance with SIPs by 1985 and high energy growth with extended power plant service life.

TABLE 2. ESTIMATED RANGE OF TOTAL LOSSES FOR THREE CROP SPECIES DUE TO OZONE AND ASSOCIATED OXIDANTS FORMED FROM ORBES POWER PLANT EMISSIONS, 1977, 1985 AND 2000

Crop	1977 Yield Reduction (10^6 Bu.)	All Scenarios, 1985[a] 2 and 2d, 2000 Yield Reduction (10^6 Bu.)	Scenario 7 2000[a] Yield Reduction (10^6 Bu.)
Soybeans			
Minimum	8.3	39.9	66.5
Maximum	72.1	113.7	156.4
Probable	31.1	62.1	94.3
Corn			
Minimum	25.4	44.5	76.3
Maximum	158.9	190.7	241.6
Probable	67.8	93.2	127.1
Wheat			
Minimum	1.6	2.7	5.1
Maximum	9.1	16.4	25.2
Probable	4.4	9.5	12.8

[a] (2) - Scenario assuming compliance with SIPs by 1985 and doubling of generating capacity by 2000

(2d) - Scenario assuming no compliance with SIPs and doubling of generating capacity by 2000

(7) - Scenario assuming compliance with SIPs by 1985 and high energy growth with extended power plant service life

The principal question is, of course, the economic significance of crop reductions of this magnitude. One must ask what is the effect for individual farm operators, for small businesses such as seed, fertilizer and equipment dealers, and for the national economy. Monetarization of these crop reductions was undertaken by Dr. Walter Page and his associates at West Virginia University as a further part of the OMBES research. I would have preferred that Dr. Page present his results directly, but since they are based on our own crop production and loss studies I will summarize by showing Tables 3 and 4 from his work. Table 3 summarizes the total 1977 value of all prospective "clean-air production", from now to the year 2000, for corn, soybeans and wheat in the five principal states plus a portion of Pennsylvania.

The complete evaluation of the benefits to agricultural production in pollutant-free air requires that we take into consideration the potential for depressed agricultural prices if, suddenly, agricultural yields were to increase as much as experimental plots have shown they could. Thus, Dr. Page's group considers the price-depressing effect of higher yield, in effect, a potential for more efficient agricultural production in relation to the inputs of fertilizer and cultivation. Most important, however, is the estimate of the total income gain to the region from higher yield (Table 4) expressed as total present discounted value of this benefit from now to the year 2000. This is a benefit value that, at least for the crops sector, can best be compared with the costs (in 1975 dollars) of major abatement initiatives. The total for the three crops is 8.1 billion dollars, or 11.9% of the total present discounted value of pollution-free production in the region from now to the year 2000. The value of future production has been discounted at the rate of 10% in all computations, but no consideration has yet been given to the

TABLE 3. PRESENT DISCOUNTED VALUE OF POLLUTION-FREE CUMULATIVE PRODUCTION, 1976-2000 (millions of 1975 dollars, assuming a 10% discount rate)

ORBES area	Corn	Soybeans	Wheat	Three-crop total
Illinois	19891.895	14151.809	1574.944	35618.648
Indiana	10694.992	5860.365	1210.970	17666.326
Kentucky	2469.632	1812.788	252.171	4534.591
Ohio	5156.554	3492.335	1055.882	9703.771
Pennsylvania	388.398	0	27.554	365.952
West Virginia	55.160	0	2.737	57.897
ORBES total	38505.632	25317.297	4124.257	67947.185

/ Calculations assume annual pollution-free output, 1976-2000, is always equal to 1976 pollution-free output and agricultural prices for the crops, in real terms, are unchanged

TABLE 4. NET PRESENT VALUE OF PROBABLE CUMULATIVE CROP LOSS,* 1976 TO 2000, FROM SO_2 AND O_3. (SCENARIO 2)

ORBES area	Total losses/ (millions of dollars)	Percent losses are of pollution-free output‡	Percent losses are of ORBES total losses
Illinois	4349.100	12.2	53.6
Indiana	2032.810	11.5	25.1
Kentucky 9 1/8	557.455	12.3	6.9
Ohio	1136.640	11.7	14.0
Pennsylvania	30.324	8.3	0.4
West Virginia	4.859	8.4	0.1
ORBES total	8111.190	11.9	100.0§

* Assumes a 10% discount rate.

/ Crops are corn, soybeans, and wheat.

‡ Discounted present values of pollution-free output are in Table 16

§ Sum may not be 100% due to rounding

potential effects on small business in the region. These effects, of course, involve responses to automobile emissions as well as utility and industry emissions.

To this date, there have been no explicit calculations for the value of oxidant effects on forest production in this region. We have estimated the current reduction in forest growth to be close to 5%. The asset value of this growth turns out to be relatively small, due to the low valuation of wood (unharvested) and the great difficulty of estimating the value of wood as a material with multiplier effects in our economy. There are also no explicit computations, as yet, for the value of either forest or crop production in other states in the northeast, in the southern and southeastern states, or in the Great Lakes states, all of which are exposed to rather similar atmospheric deposition processes.

What is the bottom line on oxidant effects for larger parts of the country? If one has to make an estimate today, one could extrapolate, I suppose, from the present studies to areas of similar size and make allowances for differences in crops and ozone exposure. For the area of New York and the rest of the east north of the North Carolina line, the total of oxidant effects could be about the same as for the ORBES area. For an area that would include Iowa and the three Great Lakes states, we could have another $8 billion in present cumulative value of losses to 2000. When we add the southeastern states, the south central region, and the California area, one has to conclude that total present cumulative value of oxidant-induced losses must approach $50 billion in terms of 1975 dollars.

Projections of the Economic Implications of All Atmospheric Deposition

In summarizing the overall economic consequences from deposition of oxidants as well as acids for agriculture, forestry, fisheries, and recreation in the north-central and north-eastern states, one enjoys a profusion of data, mostly irrelevant, and many uncertainties. Before proceeding, I want to list a few of these problem areas, and the assumptions I am making in order to proceed to preliminary conclusions.

(1) Transport of U.S. pollutants into Canada produces effects in that country, just as pollutant transport from Canada contributes to pollutant effects in the United States. Since the net transport has been shown to be more to Canada than from Canada to the United States, I will focus only on the economic consequences of the net transport to Canada; pollutant effects that are simply exchanged between the countries will remain for an accounting at another time.

(2) One way of considering economic consequences of U.S. pollutants in another country would be to consider only those that qualify as "serious, permanent and irreparable", i.e., losses which might be recoverable in the course of litigation for damages. Thus, for convenience, I will make an assumption that explicitly denies consideration of economic losses in another country that are in the nature of annual damage to crops, forests, or other resources, and where the effect could be removed immediately upon abatement of the acid inputs.

(3) Since the United States government does have a direct concern and responsibility for annual losses to crops and forests owned by

United States citizens, and for public waters under the jurisdiction of the states without their having to enter damage litigation proceedings, the monetarization of effects on these resources should be included in an accounting of U.S. economic consequences of atmospheric deposition.

The monetarized values for the ORBES region suggest that for the 118 million acres, the discounted total benefits from abatement of oxidant effects on production from now on to the year 2000 can be expressed as roughly 70 dollars per acre. This estimate excludes the effects of oxidants on forest production, materials or human health. Let me suggest that until more complete data bases become available we may be able to use these data to make some judgements about the economic effects of acidic deposition.

First of all, since oxidant effects are not permanent or irreparable, for the most part, we did not consider benefits that might accrue in Canada from abatement of effects originating with U.S. emissions. However, the more serious long-term effects of acid deposition include the loss of cation nutrients for forest production and chemically altered groundwater which can have continuing effects on fisheries throughout much of the Canadian shield. These effects require that potential benefits in Canada from control of these effects be considered. On the other hand, much of the Ohio Valley represents a relatively well-buffered soil and water system, free of long-term effects from acid inputs. Thus, the total area in Ontario, Quebec, the eastern provinces of Canada, New York, New England and the northern Appalachian states with the potential for these effects appears to be about the same size as for the ORBES region.

Secondly, the short-term and long-term effects reviewed earlier may be aggregated for purposes of summarizing income consequences. These effects

include some crop damage, some long-term effects on forest growth, fisheries losses, long-term declines in property values on acidified lakes, effects on the recreational industry in acid-sensitive regions, and costs incurred by having to treat chemically altered groundwater. The sum of benefits from abatement of these effects for regions of abundant, low-alkalinity streams and lakes, discounted to accumulate costs to the year 2000, seems likely to be of the same order as the average benefit from abatement of oxidants on annual crop yield, i.e., in the range of $50 to $100 per acre. If the total area involved is about the same as for the ORBES region, we would be talking about another $6 to $12 billion in present discounted value of prospective benefits from abatement. Since mild effects appear to be taking place now in northern Minnesota, Wisconsin and Michigan, in the national parks such as the Great Smokies and Shenandoah, and in Colorado and California, the total of prospective benefits could well approach twice these amounts, i.e., $15 to $25 billion. Recent estimates of the costs of field mitigation of effects by additions of lime to land and water surfaces indicate a similar cost for restoring the resources.

Having suggested some numerical values, however, let me draw your attention to the principles enunciated in recent reports by Dr. Thomas Crocker and his associates at the University of Wyoming. These researchers have pointed out that if the resource base is already severely diminished, possibly irreparably, there are few benefits to be gained by investments in abatement. If this is the circumstance at present in up-state New York and in parts of Ontario and Nova Scotia, then the estimate of potential benefits for this region as suggested above is outrageously high. Conversely, if the poorly-buffered regions of Wisconsin, Michigan, Minnesota, Colorado and

California are just now beginning to show effects, the benefits from abatement there may be seriously underestimated. I believe Dr. Crocker's results very aptly describe the estimation problems we face in evaluating the consequences of acidic deposition.

In proceeding with these estimates, I have tried to be responsive to the Committee's desire to have qualitative results, if necessary, as well as quantitative results where available. To some extent I have provided personal judgements, aided by prior work in Minnesota, Wisconsin, Indiana, Ontario, Quebec and Nova Scotia. I have tried to indicate how I, personally, evaluate the prospective income and asset consequences of acid deposition and oxidants over the next 20 years and continuing in the 21st century. I hope the users of this testimony will recognize, as I do, the considerable fragility of these or any other projections at this time. Perhaps this testimony will help define the more precise evaluations that are needed now of prospective benefits from control, and the implications of the resource interventions we are experiencing. I hope, too, that we may shortly begin to design the legislation and regulatory practices to reverse the trends and establish a balance between the demands we must make of our environment, and the capacity of that environment to meet the needs of future generations.

Senator MITCHELL. The next witness is Dr. William E. Sharpe of Pennsylvania State University.

Dr. Sharpe, your written statement will be included in its entirety as a part of the record. I will ask you to please take a few minutes to summarize that statement.

STATEMENT OF DR. WILLIAM E. SHARPE, ASSISTANT PROFESSOR OF FOREST RESOURCES EXTENSION AND WATER RESOURCES SPECIALIST, PENNSYLVANIA STATE UNIVERSITY, UNIVERSITY PARK, PA.

Dr. SHARPE. Thank you, Senator.

I am Dr. William E. Sharpe, assistant professor of forest resources extension at Pennsylvania State University.

For the past 8 years I have worked with small rural water suppliers in Pennsylvania on a variety of problems. Most of this effort has been with the owners of individual private water systems serving single families.

For the past 2 years I have been involved in a study of roof catchment-cistern water supplies in Clarion and Indiana Counties. These water supplies are privately owned and designed to serve single-family residences.

Our examination of roof catchment-cistern water supplies has shown that polluted precipitation results in impaired drinking water quality for users of such systems. In many cases, users of roof catchment-cistern systems have been forced to use this method

of water supply because local ground water supplies have been polluted by coal mine drainage. Ironically, it is the burning of coal that is partially responsible for the pollution of precipitation, the only source of water that remains for these individuals.

The direct effects of polluted precipitation on roof-catchment systems are:

One, increased corrosion of household plumbing systems;

Two, elevated lead concentrations that in many cases are in excess of the mandatory drinking water limit;

Three, high copper concentrations that are in excess of the recommended limit for drinking water;

Four, in a few homes cadmium levels that exceed the mandatory drinking water limit.

Millette, et al., recently reported on an Environmental Protection Agency survey of public water supplies in the United States. The results of their survey showed almost 70 percent having moderately to highly corrosive waters.

Data on lead, copper, and cadmium concentrations in tap water samples are given. The maximum values for these three metals reported by Millette, et al., are much less than those obtained in our worst case cistern study.

It is possible to infer from this that the acid precipitation being utilized almost directly by cistern water users is more corrosive than that generally being served in most public water supplies. Consequently, it seems reasonable to state that the addition of acid precipitation to Earth surface catchments will make the corrosive water already being produced by those catchments more corrosive. For many catchments located in areas of acid precipitation, this, in fact, may have already occurred.

Senator MITCHELL. Are we able to estimate any effect from that? Merely to state the proposition that, as you have, "the addition of acid precipitation to Earth surface catchments will make the corrosive water already being produced by those catchments more corrosive" does not by itself lead to the conclusion that is harmful or dangerous or bad in any way.

My question to you is this: Is it harmful, dangerous, or bad in any way?

Dr. SHARPE. I think that in view of the EPA study which shows in many cases problems with metals in tap water samples at levels currently being experienced and our results which show that if they were using precipitation directly they would probably be much worse, that is some evidence at least that the situation would probably be worse. In terms of quantifying the difference, that has not, to my knowledge, been done yet.

Senator MITCHELL. If you drink enough of it, it will be bad but you are not able to say yet how much is enough?

Dr. SHARPE. What we can say is that for the population of water users that we studied, which are people who collect rain water on their roofs, channel it into a cistern for storage and then consume it, they already have a serious problem.

What I am trying to do then is generalize from that to the greater arena of public water supply in general in the Northeast. That later generalization is the difficult one. However, as far as that segment of users that I have described, we pretty much can

say with reasonable assurance that they have a serious problem at the present time based on the data we have collected.

Senator MITCHELL. Thank you, Dr. Sharpe. Please continue.

Dr. SHARPE. We can estimate the cost of polluted precipitation to roof catchment-cistern system owners. Assuming that corrosive water and metals are the only problem, initial costs of approximately $500 per household would be required to purchase and install some sort of water neutralizing device.

Along with this, the cistern should be cleaned to remove lead-laden sediments. In addition, a settling basin should be installed to allow precipitation of the lead contained in the neutralized water. This basin also will need rather routine cleaning.

Plumbing systems in these homes should be converted to nonmetallic components to prevent corrosion by the treated water. Costs per household, assuming that these treatments are all that is necessary, could easily amount to $2,500 per household. If there are other as yet undiscovered problems, the cost could be higher.

A recent report stated that in the State of Ohio there are 67,000 roof catchment-cistern water systems present. If half of these systems were required to spend the $2,500 to avoid metal problems, the total cost would be around $84 million.

For other water supplies the current costs of corrosion are considerably greater, although we cannot attribute all these costs to acid rain. Speaking generally about corrosion costs now as a problem for public water supplies, Kenneth Shull reports in the May 1980 issue of the Journal of the American Water Works Association that the cost of underground pipeline maintenance and replacement due to corrosion is $600 million annually in the United States. Of this he says that at least $150 million is spent by the water utility industry.

Robert A. Ryder in an article in that same issue of the AWWA Journal gives an annual cost figure of $70 billion for the total costs of corrosion in the United States in 1975. That would include corrosion from all sources and for all reasons. Of this, $700 million is attributed to the water supply field.

Ryder reports on corrosion control cost studies for the city of Seattle, Wash. He estimates that the annual costs of water system corrosion in Seattle for plumbing and water distribution systems is about $7.4 million.

In conclusion, it is obvious that corrosion control is a big problem for many water suppliers. It is equally as obvious that corrosion is a problem even in the absence of polluted precipitation. What I am saying there is that we have corrosion problems and we would still have them even if we did not have acid precipitation.

Senator MITCHELL. This just makes it worse?

Dr. SHARPE. Yes.

Senator MITCHELL. It makes an existing problem worse?

Dr. SHARPE. Yes.

I am not aware of the existence of any data showing the portion of current corrosion control costs that are due to polluted precipitation. It should be remembered that even unpolluted precipitation would still be corrosive to plumbing systems.

Nevertheless, I personally feel that a close examination of the situation will reveal that there are significant water system corro-

sion costs as a result of polluted precipitation. Certainly, the impacts seem to be clear for those who depend on roof catchment-cistern water supplies. Acid precipitation can only make the very bad problem of water system corrosion worse.

Senator MITCHELL. You talked about 67,000 homes in Ohio estimated with cistern water systems. Are those generally systems that are utilized in the homes of persons at the lower end of the economic scale of this country or are those systems distributed throughout the economic scale?

Dr. SHARPE. I cannot speak for the State of Ohio. I can only speak for the 40 homes that are in our Pennsylvania study and observations of other homes in the areas where we are working. Generally they are evenly distributed among the socioeconomic classes.

Most of the new homes being constructed, some of them in the medium-price range for new housing, have cistern water systems in the rural area at which we are looking because it is the only available water supply to these people.

Senator MITCHELL. Therefore, it depends more on location than on income of the owner?

Dr. SHARPE. I would guess so, yes.

Senator MITCHELL. Thank you very much, Dr. Sharpe. We appreciate your testimony.

[The prepared statement of Dr. Sharpe follows:]

Statement of Dr. William E. Sharpe, Assistant Professor of Forest Resources Extension and Water Resources Specialist, The Pennsylvania State University, to a joint hearing of the Senate Small Business Committee and the Committee on Environment and Public Works, September 23, 1980.

I am Dr. William E. Sharpe, Assistant Professor of Forest Resources Extension at The Pennsylvania State University. For the past 8 years I have worked with small, rural water suppliers in Pennsylvania on a variety of problems. Most of the effort has been with the owners of individual private water systems serving single families. For the past two years I have been involved in a study of roof catchment-cistern water supplies in Clarion and Indiana Counties. These water supplies are privately owned and designed to serve single family residences. They consist of a rainfall catchment area, usually the house roof, and a large concrete or cinder block storage reservoir or cistern. Most of these systems have been designed and built by the individual homeowner's themselves. As might be expected each system is, therefore, somewhat unique.

In reviewing the possible effects of acid rain on water supplies it becomes apparent that a system such as that just described is the most susceptible to water quality impacts. In a roof catchment-cistern water supply, rain and snow are collected on the roof and channelled directly to the cistern. The quality of the water is little changed by the process; consequently, if the rain and snow are polluted, the cistern will be also. Furthermore, pollutants that fall out of the air onto the roof when it is not raining or snowing, so called "dry fallout," also have a negative impact on the quality of cistern water. In all other types of water supplies this is not the case. In these water supplies rain and snow will be altered in quality by natural processes. In most cases these natural processes will result in a net improvement in water quality. Roof catchment-cistern water systems, therefore, comprise a "worst case" situation. By looking at the "worst case" water supply situation it is sometimes possible to guess with some accuracy what impacts are likely in other types of water supplies where the effects are not expected to be as great. For instance, if corrosion of household plumbing by acid precipitation is <u>not</u> a problem in roof catchment-cistern water supplies then it is unlikely that it will be a problem in other types of water supplies.

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Such hypotheses are dangerous in that complicating factors may be present, but they are sometimes necessary when supporting data is not available.

Our examination of roof catchment-cistern water supplies in the rural countryside of Clarion and Indiana Counties, Pennsylvania has shown that polluted precipitation results in impaired drinking water for users of such systems. In many cases users of roof catchment-cistern systems have been forced to use this method of water supply because local groundwater supplies have been polluted by coal mine drainage. Ironically, it is the burning of coal that is partially responsible for the pollution of precipitation, the only source of water that remains for these individuals.

The direct effects of polluted precipitation on roof-catchment systems are:

1) Increased corrosion of household plumbing systems
2) Elevated lead concentrations that in many cases are in excess of mandatory drinking water limit
3) High copper concentrations that are in excess of the recommended limit for drinking water
4) In a few homes cadmium levels that exceed the mandatory drinking water limit.

There may be other airborne contaminants such as mercury, arsenic and PCB's present in roof catchment systems that as yet have not been evaluated in our study.

The most significant water quality problem is posed by lead. It's source in cistern water supplies is twofold. First, it enters the system directly as a component of polluted precipitation. Our study found significant concentrations of lead in bulk precipitation even in the rural countryside where the study was conducted. Secondly, the corrosion of the lead/tin solders used in household plumbing systems results in further contributions of lead. Over 50 percent of the houses studied had lead levels in excess of drinking water limits at some point in the system. The highest lead concentrations in most of the homes were in the sediments that collect on the bottom of the cistern. Samples of the very first water drawn from the kitchen cold water faucet for the day also frequently contained high lead concentrations.

Cadmium concentrations were below drinking water limits in all but four homes. Cadmium concentrations are likely to be higher in homes with galvanized plumbing system components. Most homes in the study did not have a great amount of galvanized plumbing.

Copper was present in the first flush tap water samples of many homes at levels in excess of the recommended drinking water limit. The levels of copper found in this study are non-toxic to humans, but they may impart an objecticnable, bitter taste to the water. The presence of relatively large amounts of copper in the tap water samples is further evidence of household plumbing system corrosion.

The Environmental Protection Agency recommends that drinking water be non-corrosive. Test of the corrosivity of bulk precipitation showed it to be highly corrosive.

As I stated at the beginning of this testimony, roof catchment-cistern water systems can be thought of as representing the "worst case" among water supplies with regard to the water quality impacts of polluted precipitation. I would like now to expand further on this essential point.

There are two primary sources of most drinking water. These are earth surface catchments or watersheds and ground water reservoirs. Within these major water supply types, there are further variations in the actual nature of the supply. Each of these variations is likely to have a different susceptibility to polluted precipitation.

Next to roof catchment cisterns the most susceptible water supply is the surface catchment located in an area of resistant bedrock, acidic, shallow, stony soils, steep slopes, intense storms and coniferous vegetation. In a watershed of this type there is likely to be a minimum of contact between rainfall and the rocks, soils and vegetation that would filter out impurities and alter the water chemically. If these materials are by nature already acid then the likelihood of substantial improvements in the chemistry of the precipitation is further reduced.

Conversely, surface catchments with greater amounts of reactive rock, deeper soils, gentler slopes, less intense storms and more deciduous vegetation have diminished susceptibility to water quality degradation from polluted precipitation.

Althoughh little data exists on the impact of polluted precipitation on surface water supplies, some generalizations can be made about these impacts. Based on the "worst case" study of lead concentrations and the tendency of metals to be readily absorbed by soil, it is unlikely that the metals of polluted precipitation constitute a threat to surface-catchment water supplies. That precipitation which falls directly upon

reservoirs and streams feeding those reservoirs will be diluted to acceptable concentrations.

However, secondary effects of polluted precipitation have a much greater potential impact. Leaching of metals contained in soils and subsequent entrance of these metals into water supplies is a possible source of drinking water impact that should be investigated further.

Potentially more serious is the increased corrosiveness of water in such water supplies as a consequence of acid rain. Changes in the pH of lakes and reservoirs has been documented in certain sectors of the country. Such changes are indicative of increased corrosion potential which could lead to greater solution of metals from plumbing systems and a potential health hazard. This problem is most significant for the small surface water supply with limited system storage capacity and treatment facilities. In such systems even the temporary increases in water corrosivity resulting from sudden storms or winter snowmelt are likely to be significant. Small systems such as this serve many communities in rural America. Their limited storage capacity dictates that they must take water into their systems almost continuously to meet demands. This

allows little opportunity for dilution of the more acid water associated with storm and snowmelt events. Little data are as yet available on this problem, but indications are that small water systems with susceptible surface catchments are highly susceptible to increased corrosion as a consequence of acid runoff events.

Of Pennsylvania's 850 or so public water supply utilities approximately 90 percent use surface water as a source of supply. In much of the Northeast surface water is the chief source of water supply.

Millette et al. (1) recently reported on an Environmental Protection Agency survey of public water supplies in the United States. The results of their survey showed almost 70 percent having moderately to highly corrosive waters. Data on lead, copper and cadmium concentrations in tap water samples are given. The maximum values for these three metals reported by Millette et al. are much less than those obtained in our "worst case" cistern study. It is possible to infer from this that the acid precipitation being utilized almost directly by cistern water users is more corrosive than that generally being served in most public water supplies. Consequently, it seems reasonable to state that the addition

of acid precipitation to earth surface catchments will make the corrosive water already being produced by those catchments more corrosive. For many catchments located in areas of acid precipitation, this, in fact, may have already occurred.

The least susceptible type of water supply to pollutant precipitation is the ground water supply. Among ground water supplies shallow systems are more susceptible than deeper ones. Because most ground water is filtered by soil before it enters the system, metals and other contaminants are removed. The water is also altered chemically to have increased pH and less corrosivity.

Any water supply derived from soils and bedrock high in reactive carbonaceous materials will be much less susceptible to water quality impacts arising from polluted precipitation. Those surface watersheds and groundwater systems arising from soils and bedrock low in reactive carbonaceous materials will be the most susceptible.

The economic impact of polluted precipitation on water supplies is difficult to assess. There is very little available information on the impacts themselves let alone the economics of those impacts.

We cannot estimate the cost of polluted precipitation to roof catchment-cistern system owners. Assuming that corrosive water and metals are the only problem, initial costs of approximately $500 per household would be required to purchase and install some sort of water neutralizing device. Along with this the cistern should be cleaned to remove lead laden sediment. In addition a settling basin should be installed to allow precipitation of the lead contained in the neutralized water. This basin will need rather routine cleaning to remove lead contaminated sediments. The plumbing systems in the homes should be converted to non-metallic components to prevent corrosion by the treated water. Costs per household assuming that these treatments are all that is necessary could easily amount to $2,500. If other, as yet undiscovered problems are present a new supply of water may have to be obtained at considerably higher cost.

A recent report stated that there are an estimated 67,000 roof catchment-cistern systems in the state of Ohio alone. If half of these systems were required to spend $2,500 on water treatment equipment the total cost would be $83,750,000.

For other water supplies the current costs of corrosion are much greater. Kenneth E. Shull (2) reports in the May, 1980 issue of the Journal of the American Water Works Association that the cost of underground pipeline maintenance and replacement due to corrosion is 600 million dollars annually in the United States. Of this he says that at least 150 million is spent by the water utility industry. Robert A. Ryder (3) in an article in that same issue of the AWWA Journal gives an annual cost figure of 70 billion dollars for the total costs of corrosion in the United States in 1975. Of this, 700 million is attributed to the water supply field. Ryder reports on corrosion control cost studies for the city of Seattle, Washington. He estimates that the annual costs of water system corrosion in Seattle for plumbing and water distribution systems is 7.4 million dollars. He further states that the greatest costs are incurred in residential plumbing systems. Ryder found that addition of corrosion control chemicals could reduce water system corrosion by a maximum of 25 percent.

It is obvious that corrosion control is a big problem for many water suppliers. It is equally as obvious that corrosion is a problem

even in the absence of polluted precipitation. I am not aware of the existence of any data showing the portion of current corrosion control costs that are due to polluted precipitation. It should be remembered that unpolluted precipitation is also corrosive to water distribution systems. Nevertheless, I personally feel that a close examination of the situation will reveal that there are significant water system corrosion costs as a result of polluted precipitation. Certainly, the impacts seem to be clear for those who depend on roof catchment-cistern water supplies. Acid precipitation can only make the very bad problem of water system corrosion, worse.

Literature Cited

1. Millette, J. R. et al. Aggressive Water: Assessing the Extent of the Problem. American Water Works Association Journal, 72:5:262 (May 1980).

2. Shull, K. E. An Experimental Approach to Corrosion Control. American Water Works Association Journal, 72:5:280 (May 1980).

3. Ryder, R. A. The Costs of Internal Corrosion in Water Systems. American Water Works Association Journal, 72:5:267 (May 1980).

Senator MITCHELL. The final witnesses this morning will be Dr. Norbert Baer of New York University and Mr. John Yocom of TRC–Environmental Consultants, Inc.

Good morning, gentlemen.

We look forward to your presentations. We have approximately 18 minutes left before we have to leave this room. Please proceed.

Your presentation will provide a little visual diversion. I gather we have some slides to be shown.

STATEMENT OF DR. NORBERT S. BAER, PROFESSOR AND CO-CHAIRMAN, CONSERVATION CENTER, INSTITUTE OF FINE ARTS, NEW YORK UNIVERSITY

Dr. BAER. I am Norbert Baer, professor of conservation and cochairman of the Conservation Center of the Institute of Fine Arts, New York University.

I appear before you to focus on one aspect of materials damage due to environmental effects, that of damage to historic masonry buildings and monuments. These historic and artistic works represent the single most visible aspect of our history and culture.

Today the visitor often finds his view of a monument obscured by a maze of scaffolding erected in the attempt to limit the destruction and to salvage at least part of what remains.

Major campaigns are under way or have been announced in Athens, Cologne, London, Paris, Rome, Venice, Vienna, and an ever-growing international list of cities large and small.

[Slides shown.]

Dr. BAER. Here we see Trajan's Column in Rome.

[Slide shown.]

Dr. BAER. Here is a second view of it.

[Slide shown.]

Dr. BAER. That is the Erechthion on the Acropolis as the Caryatids are being prepared to be removed.

[Slide shown.]

Dr. BAER. Here we see a sculpture in the Place de la Concorde in Paris.

[Slide shown.]

Dr. BAER. Here we see the Church of the Scalzi in Venice.

[Slide shown.]

Dr. BAER. Here we see a mausoleum in Aurangabad in India. In each of these cases——

Senator MITCHELL. You cannot see the sights because of the scaffolding.

Dr. BAER. That is exactly the point. In fact, in some cases the situation is so severe that it is being used as a way of trying to focus attention on the problem by trying to get tourist complaints over the fact that the monuments are inaccessible. This is certainly the case in Rome.

Senator MITCHELL. That is what we are doing here, only in a different manner.

Dr. BAER. That is right.

Two questions immediately come to mind: What is the cause of this seemingly universal attack? What can we do to combat it?

It is generally agreed that the most serious threat to stone monuments derives from airborne pollutants. One need only identi-

fy the constituents of the crumbling black crust formed on the surface of an outdoor sculpture to learn that oxides of sulfur have participated in a chemical reaction converting a highly polished, hard marble surface to a powdery spalling crust of soot impregnated calcium sulfate.

[Slides shown.]

Dr. BAER. We have here three examples from Venice. These are not major sculptures in Venice. The artists may not even be known, but the sculptures certainly are an important part of the architectural heritage in Venice. I think this is a particularly dramatic example of what happens ultimately as the effect of air pollutants takes its toll.

Senator MITCHELL. On that site what is the original and what is the effect?

Dr. BAER. The original would be the sculpture itself. Underneath what you are seeing is the bare marble as the original surface is simply spalled off in a layer that may be 1 or 2 millimeters thick.

We are seeing two effects there. One is, of course, the development of this black sooty crust which is in part a chemical reaction and in part a deposition of particulate matter from the refineries and chemical industries surrounding Venice in this case. After a while that reaction proceeds so deeply that you have massive chunks of the material simply falling loose.

The white color is the color that the stone would have had originally. Of course, it would have been polished and shaped. You have these irregular breaks, especially in areas where there was high tooling on the part of the sculptor.

In its most ubiquitous form this surface deposition may be seen as the black coating which obscures the surface of so much of our urban architecture. Virtually all of that particulate matter is man made. Its economic costs are enormous.

Millions of dollars are spent each year to clean stone buildings in New York City alone. St. Patrick's Cathedral, the Plaza Hotel, the Vuillard Houses, Grand Central Terminal, the Woolworth Building, and the U.S. Customs House at Bowling Green have all been cleaned or are scheduled for cleaning in the near future.

This cleaning should not be thought of as having only esthetic value. The black crust is considered by many to form a surface catalytic to the formation of acids from gaseous air pollutants. These acids in turn attack the stone leading to structural failure.

Other less immediately visible effects lead to the erosion of surface detail with eventual reduction to formlessness. As a result, archeologists, architects, and art historians are often faced with the cruel choice of preservation by replacement, that is, moving the original to a controlled museum environment and replacing it with a copy.

We can all appreciate the anguish of our Greek colleagues when they were forced to remove the Caryatids from the Erechthion. For 2 milleniums the glorious maidens had graced the Acropolis. Now, replaced by copies, they may only be seen out of context.

Surface coatings have been applied to treat surfaces in situ, often with disastrous results. More often than not this superficial treatment has done more harm than good.

It is often said that we have seen more damage to our monuments during the past 40 years than they had suffered in their previous history. There is little—and I should emphasize this point—in the way of firm documentation for these assertions. In some cases we are obviously observing the accumulated result of many years of exposure to air pollution. For example, descriptions of urban England in the 19th century demonstrate a high level of airborne pollutants.

That these phenomena are of a continuing nature makes it still more important to act now. Once the initial period of slow chemical reaction on a relatively intact surface has ended, a new, more destructive, and more rapid period is entered. Increased porosity, loss of surface finish, surface deposition all combine to render the monument more vulnerable to attack.

The precise mechanism whereby the attack occurs is still the subject of investigation. The specific roles of aerosols, gaseous oxides of sulfur and nitrogen, acid precipitation, and particulate matter have not yet been assigned.

[Slide shown.]

Dr. BAER. Here we have a listing of both the anthropogenic and the natural factors which play a role in the erosion of stone. There are certainly enough anthropogenic factors there to justify our concern.

To develop the most effective strategies for preservation we should have good data on the sources of pollution, the mechanisms of attack, and effectiveness and cost of various preservation approaches. Through major research efforts we are learning a great deal about the source of pollution. Unfortunately, we have only limited research which has been conducted on mechanisms of attack.

In our own case with EPA funding we are using marble gravestones in VA cemeteries distributed throughout the United States.

[Slide shown.]

Dr. BAER. This is Cypress Hills Cemetery in New York.

We are following the rate of degradation on these tombstones because they come from three sources only and are made to very rigid specifications and have been put in place over the past 100 years under the various Department of the Army and then finally VA programs for national cemeteries.

[Slides shown.]

Dr. BAER. The difference you see between the two tombstones is due to 20 years of exposure in Cypress Hills Cemetery in New York.

Under the sponsorship of the NATO Committee on the Challenges of Modern Society, a pilot study under Greek leadership has begun to develop international cooperative efforts in the conservation of historic stone monuments.

Similarly, the National Academy of Sciences is sponsoring a symposium to bring together many hitherto underutilized areas of scientific expertise. I note these two efforts because they highlight our concern and demonstrate our need for greater knowledge.

Without a full understanding of all aspects of this complex problem, economic projections are of little value. However, it is obvious that in the destruction of cultural property materials damage ef-

fects are magnified, for it is not the limited mass of material lost which is at issue but rather the loss of an irreplaceable part of our cultural heritage.

Thank you.

Senator MITCHELL. Thank you very much, Dr. Baer.

[The prepared statement of Dr. Baer follows:]

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STATEMENT BY

NORBERT S. BAER, PROFESSOR AND CO-CHAIRMAN, CONSERVATION CENTER, INSTITUTE OF FINE ARTS, NEW YORK UNIVERSITY
BEFORE THE SENATE SMALL BUSINESS COMMITTEE AND COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS HEARING ON "THE POSSIBLE COSTS TO THE ECONOMY OF ACID RAIN."

23 September 1980

I am Norbert Baer, Professor of Conservation and Co-Chairman of the Conservation Center of the Institute of Fine Arts of New York University. I appear before you to focus on one aspect of materials damage due to environmental effects, that of damage to historic masonry buildings and monuments. These historic and artistic works represent the single most visible aspect of our history and culture. Today, the visitor will often find his view of a monument obscured by a maze of scaffolding erected in the attempt to limit the destruction and to salvage at least a part of what remains. Major campaigns are underway or have been announced in Athens, Cologne, London, Paris, Rome, Venice, Vienna, and an ever growing international list of cities large and small. Two questions immediately come to mind. What is the cause of this seemingly universal attack and what can we do to combat it. It is generally agreed that the most serious threat to stone monuments derives from air borne pollutants. One need only identify the constituents of the crumbling black crust formed on the surface of an outdoor sculpture to learn that oxides of sulfur have participated in a chemical reaction converting a highly polished, hard marble surface to a powdery spalling

crust of soot impregnated calcium sulfate. In its most ubiquitous form this surface deposition may be seen as the black coating which obscures the surface of so much of our urban architecture. Virtually all of that particulate matter is man-made. Its economic costs are enormous. Millions of dollars are spent each year to clean stone buildings in New York City alone. St. Patrick's Cathedral, the Plaza Hotel, the Vuillard Houses, Grand Central Terminal, the Woolworth Building, and the U.S. Customs House at Bowling Green have all been cleaned or are scheduled for cleaning. This cleaning should not be thought of as having only aesthetic value. The black crust is considered by many to form a surface catalytic to the formation of acids from gaseous air pollutants. These acids in turn attack the stone leading to structural failure. Other less immediately visible effects lead to the erosion of surface detail with eventual reduction fo formlessness. As a result, archaeologists, architects and art historians are often faced with the cruel choice of preservation by replacement, moving the original to a controlled museum environment and replacing it with a copy. We can all appreciate the anguish of our Greek colleagues when they were forced to remove the Caryatids from the Erechthion. For two millenia the glorious maidens had graced the Acropolis. Now, replaced by copies, they may only be seen out of context.

Surface coatings have been applied to treat surfaces in-situ often with disastrous results. More often than not this superficial treatment has done more harm than good.

It is often said that we have seen more damage to our monuments during the past 40 years than they had suffered in their previous

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history. There is little in the way of firm documentation for these assertions. In some cases we are obviously observing the accumulated result of many years of exposure to air pollution. For example, descriptions of urban England in the 19th century demonstrate a high level of air-borne pollutants. That these phenomena are of a continuing nature makes it still more important to act now. Once the initial period of slow chemical reaction on a relatively intact surface has ended, a new, more destructive, and more rapid period is entered. Increased porosity, loss of surface finish, surface deposition all combine to render the monument more vulnerable to attack. The precise mechanism whereby the attack occurs is still the subject of investigation. The specific roles of aerosols, gaseous oxides of sulfur and nitrogen, acid precipitation and particulate matter have not yet been assigned. To develop the most effective strategies for preservation we should have good data on the sources of pollution, the mechanisms of attack, and effectiveness and cost of various preservation approaches. Through major research efforts we are learning much about sources of pollution. Unfortunately, only limited research has been conducted on mechanisms of attack. We, with EPA funding, are using marble gravestones in VA cemeteries distributed throughout the United States as a model material for exposure site evaluation of anthropogenic and weathering phenomena. Others are concerned with the effects of acid precipitation on metals, with particular emphasis on zinc coatings. Under the sponsorship of the NATO Committee on the Challenges of Modern Society (CCMS), a Pilot Study under Greek leadership has begun to develop international cooperative efforts in the Conservation of Historic

Stone Monuments. Similarly, the National Academy of Sciences is sponsoring a symposium to bring many hitherto underutilized areas of scientific expertise to bear on the problem. I note these two efforts because they highlight our concern and demonstrate our need for greater knowledge. Without a full understanding of all aspects of this complex problem, economic projections are of little value. However, it is obvious that in the destruction of cultural property materials damage efforts are magnified, for it is not the limited mass of material lost which is at issue but rather the loss of an irreplaceable part of our cultural heritage.

Acid rain eats away at our world

Prof. Herbert G. Ohrt of New York University's Institute of Fine Arts is studying the acid rain damage on the 19,000 headstones at the Cypress Hills Cemetery on the Brooklyn-Queens border.

Tart as lemon, it erodes tombstones, and turns statues green

Senator MITCHELL. Mr. Yocom?

STATEMENT OF JOHN E. YOCOM, VICE PRESIDENT AND CHIEF CONSULTING ENGINEER, TRC-ENVIRONMENTAL CONSULTANTS, INC.

Mr. YOCOM. I have a few slides to show, and since we arre already set up, I will go through quickly.

[Slide shown.]

Mr. YOCOM. That is a downspout that has been badly corroded. This is the only slide of many that I have that actually demonstrates a direct acid rain effect. I will be talking about effects on a variety of materials, but this shows the effect on zinc and steel.

[Slide shown.]

Mr. YOCOM. This is taken in a cemetery around New York City. It shows a statue probably no older than 50 to 100 years. It has been very significantly damaged by air pollution and/or acid rain. There is no way of really telling which it is.

This is probably more a problem of poor selection of stone. This is made of very soft materials, so perhaps this is not a very good example of what would normally happen with high quality marble, for example.

[Slide shown.]

Mr. YOCOM. Dr. Baer has already alluded to the situation on the Acropolis. This is a view of the Parthenon. The problem here is one not only of surface degradation from, let's say, a combination of acid rain, air pollution, but in addition there have been, at various times, attempts to go through and restore various parts of the buildings on the Acropolis. Steel pins were put in to help hold the old buildings together. Of course, what has happened over the years is that the acidic material has corroded the pins, they have expanded, and actually produced more damage than if the pins had not been put in there.

[Slide shown.]

Mr. YOCOM. This is an example of surface soiling and loss of surface detail on the Parthenon. The loss of detail on outside surfaces is a little bit subtle but it shows the surface degradation, a certain softness, that you get from the effect of air pollution and moisture on the outside white surface.

[Slide shown.]

Mr. YOCOM. This picture is taken, I guess, a year earlier than your picture, Dr. Baer. It shows the efforts to protect the Caryatids on the Erechthion. At this point they actually have been removed and put into a museum.

The effects of acid rain on buildings, monuments, and other nonliving material surfaces do not fit the usual scenario of acid rain. These material surfaces exist in greatest abundance in urban and industrial areas close to sources of primary pollutants and not in those remote areas where acid rain is believed to be a problem. However, this is not to say that acid rain does not exist and produce materials damage within these urban areas.

The point is that the effects of acid rain on materials must be considered within the broader context of direct and indirect effects of air pollution on materials.

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However, I hasten to point out that there is no significant body of information on the specific effects of acid rain on materials in relation to other environmental effects, nor is there any information on the economic effects of acid rain specific on materials.

Senator MITCHELL. To your knowledge, are there any studies with a specific objective of developing that information now in existence?

Mr. YOCOM. None that I know of. I think this is certainly an area where research needs to be done. It is within that broader context of the total effects of air pollution. Very little is known about the full situation.

There is no question that the presence of air pollutants, notably sulfur oxides, nitrogen oxides, and particulate matter, under the proper circumstances can exacerbate damage to inanimate materials, thereby producing costs to society.

This problem has been recognized for well over 300 years. In 1661 John Evelyn, a public-spirited citizen of London, described the air pollution situation in London as follows:

> This is the pernicious Smoake which sullyes all her Glory, superinducing a sooty Crust or Fur upon all that it lights, spoyling the moveables, tarnishing the Plate, Gildings and Furniture, and corroding the very Iron-bars and hardest Stones with these piercing and acrimonious Spirits which accompany its Sulphure; and executing more in one year, than exposed to the pure Aer of the Country it could effect in some hundreds.
>
> It is this horrid Smoake which obscures our Churches, and makes our Palaces look old, which fouls our Clothes, and corrupts the Waters, so as the very Rain, and refreshing Dews which fall in the several Seasons, precipitate this impure vapour, which, with its black and tenacious quality, spots and contaminates whatever is exposed to it.

Certainly his pointing out of sulfur and acid rain as causative agents I consider to be prophetic, but his use of "sulphure" as used in his pamphlet probably had more to do with emanations from the nether regions than any special knowlege of the chemistry of sulfur.

In my testimony I have presented a brief table that summarizes the effects of air pollution on several classes of materials along with the listing of the environmental factors that influence these effects.

Take, for example, building stone. The kind of damage we have seen is surface erosion and discoloration. The principal pollutants would be sulfur oxides and/or acid rain and particulate matter.

I think it is more important to mention those other environmental factors that affect damage. They include moisture in many forms and in many mechanisms of contact, temperature fluctuations such as freezing and thawing, salt, mechanical vibrations from traffic—this is a severe problem in some of the cathedrals in Europe—microorganisms, and carbon dioxide.

Important points to be brought out from this type of information are:

One, a variety of materials are damaged by air pollutants.

Two, sulfur oxides figure prominently as a pollutant type which can cause damage to many materials.

Three, air pollution is only one of the environmental factors that can cause damage to materials exposed to outdoor atmospheres. I think this has already been brought up. We are dealing with one

effect superimposed on others which occur even in the natural environment.

Senator MITCHELL. Your conclusion is not significantly different from that of Dr. Sharpe. He talked about a specific area of water supplies; that is, that there is a broad problem. This probably aggravates the problem. The degree to which it does we do not know. Is that a fair statement of your conclusion with respect to building materials?

Mr. YOCOM. Exactly.

This last mentioned point regarding the effect of moisture brings up the connection with acid rain. The corrosion of metals and damage to building stone as influenced by sulfur oxides require that moisture be present. Therefore, it is a difficult task to isolate the specific effect of a pollutant, or let's say acid rain, from the effects of moisture and many other environmental effects that influence it.

Many attempts have been made to estimate the costs of material damage caused by air pollution. Most of these estimates are completely unreliable, largely because many assumptions are necessary; for example, assumptions on the quantities of materials exposed, the exact mechanisms of physical damage, and the scenarios of material protection, repair, and replacement.

The most accurate estimate in my estimation of material damage costs from air pollution was limited to the effects of sulfur oxide on metals—in other words, an exacerbation of the corrosion of metals. This estimate showed that metal damage costs have dropped significantly as a result of sulfur oxide emission control efforts.

In this paper to which I am referring, which is referenced in the testimony, is that in 1968 there was $900 million damage which had been reduced to $75 million, a decrease of over 90 percent between 1968 and 1972.

Senator MITCHELL. Speaking of estimates of damage, do you have an opinion as to the reasonableness of the estimate by Dr. Loucks who testified earlier about damage in another area? You were sitting there listening. What is your reaction to that? Is that reliable? Can I get up on the floor of the Senate and use that with some degree of assurance?

Mr. YOCOM. I could not judge. Unless I had reviewed and determined the basis of that number, I would not want to say whether it is correct or not.

One of the problems is that there are people making estimates using data that have been developed by others which have not been checked for accuracy. There is layer upon layer of estimate. Any errors tend to be compounded and in many cases magnified. That is certainly the situation in estimates of material damage costs.

This also points out another problem in estimating the extent and cost of air pollution damage. That is that the situation is continually changing. As we saw in this one report to which I referred, sulfur dioxide has dropped by 90 percent in a period of about 4 years just because of air pollution control activities. It is a changing target. Damage which you go out and assess today may have been caused many, many years ago by an integration of effects up to this time. Therefore, it is a very difficult estimation process.

A further complicating factor is that there have been significant changes in the types of materials and protective coatings exposed to the atmosphere. These technological changes include the increased use of materials more resistant to pollutant damage. In our "throw-away" economy materials are often discarded long before the effects of air pollution become significant.

I think one of the inaccuracies of a lot of these estimates is the assumptions that are made on the rate of replacement or what the scenario is of repair or refurbishment.

The recycling and preservation of old buildings as a result of high costs for new construction and a greater interest in our architectural heritage runs counter to our throw-away tendencies. This trend will place increased importance on effects of air pollution, acid rain, and other environmental stresses on older material surfaces, because the useful life of materials is a key element in determining damage costs.

In summary, I have tried to make the following points:

One, air pollution and acid rain are capable of damaging materials, but much more work is needed to establish the most important mechanisms of damage.

Two, there are no accurate estimates of the extent of the physical and economic damage from acid rain. Studies are needed to establish these factors, especially during this period of increasing reliance on coal as a fuel and raw material.

Three, in those parts of our economy where we are attempting to preserve buildings and structures, special attention should be given to the air pollution and acid rain damage scenarios and the costs for preservation and maintenance.

Thank you.

Senator MITCHELL. Mr. Yocom, your statement in its entirety will be placed in the hearing record.

Thank you very much, Mr. Yocom and Dr. Baer.

I want to thank all of you ladies and gentlemen who have come here to testify today. It has been most interesting and enlightening. It is my hope that your testimony will serve as a basis, at least part of a basis, for action by the Congress in what is plainly an area of serious concern, or should be an area of serious concern, to the Nation. For your contribution, we are all deeply grateful.

This hearing will now be adjourned. Thank you again.

[Whereupon, at 12:02 p.m., the hearing adjourned.]

[The prepared statement of Mr. Yocom follows:]

STATEMENT BY

John E. Yocom, Vice President and
Chief Consulting Engineer
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125 Silas Deane Highway
Wethersfield, CT 06109

before

Senate Small Business Committee and
Committee on Environment and Public Works

on

The Possible Costs to the Economy of Acid Rain

Title of Statement: Effects of Air Pollution and Acid Rain on Materials

Date of Statement: September 23, 1980

Acid rain is a poorly understood phenomenon which has only recently drawn the attention of the scientific community in this country. Acid rain is thought to be largely the result of the long range transport of air pollutants such as sulfur oxides, their conversion in transit to sulfates, and their deposition in or along with rainwater in pristine, ecologically sensitive areas. Possible effects of acid rain on buildings, monuments and other non-living material surfaces do not fit this scenario. These material surfaces exist in greatest abundance in urban and industrial areas close to sources of primary pollutants and not in those remote areas where acid rain is believed to be a problem. However, this is not to say that acid rain does not exist and produce materials damage within urban areas. The point is that the effects of acid rain on materials must be considered within the broader context of direct and indirect effects of air pollution on materials. However, I hasten to point out that there is no significant body of information on the effects of acid rain on materials in relation to other environmental effects, including

the direct action of pollutants, nor is there information on the economic effects of acid rain on materials.

There is no question that the presence of air pollutants, notably sulfur oxides, nitrogen oxides, and particulate matter under the proper circumstances can exacerbate damage to inanimate materials thereby producing costs to society. Material damage related to air pollution has been recognized for well over 300 years. In 1661 John Evelyn, a public spirited citizen of London, described the air pollution situation in London as follows:*

> "This is the pernicious Smoake which sullyes all her Glory, superinducing a sooty Crust or Fur upon all that it lights, spoyling the moveables, tarnishing the Plate, Gildings and Furniture, and corroding the very Iron-bars and hardest Stones with these piercing and acrimonious Spirits which accompany its Sulphure; and executing more in one year, than exposed to the pure Aer of the Country it could effect in some hundreds.
>
> It is this horrid Smoake which obscures our Churches, and makes our Palaces look old, which fouls our Clothes, and corrupts the Waters, so as the very Rain, and refreshing Dews which fall in the several Seasons, precipitate this impure vapour, which, with its black and tenacious quality, spots and contaminates whatever is exposed to it."

His pointing out of sulfur and acid rain as causative agents appears prophetic, but "sulphure" as used in his pamphlet undoubtedly had more to do with emanations from the nether regions than any special knowledge of sulfur chemistry as related to air pollution effects.

The following table summarizes the types of damage that can be caused by air pollution.

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*Evelyn, J., Fumifugium: or the Smoake of London Dissipated, 1661 (National Smoke Abatement Society Reprint 1933).

AIR POLLUTION DAMAGE TO MATERIALS

Materials	Type of Damage	Principal Air Pollutants	Other Environmental Factors
Metals	Corrosion, Tarnishing	Sulfur Oxides & Other Acid Gases	Moisture, Air, Salt
Building Stone	Surface Erosion & Discoloration	Sulfur Oxides & Other Acid Gases, Particulate Matter	Moisture, Temperature Fluctuations, Salt, Vibrations, Microorganisms, CO_2
Paint	Surface Erosion, Discoloration	Sulfur Oxides, Hydrogen Sulfide, Ozone, Particulate Matter	Moisture, Sunlight, Microorganisms
Textiles	Reduced Tensile Strength, Soiling	Sulfur Oxides, Nitrogen Oxides, Particulate Matter	Moisture, Sunlight
Textile Dyes	Fading, Color Change	Nitrogen Oxides, Ozone	Sunlight
Paper	Embrittlement	Sulfur Oxides	Moisture
Rubber	Cracking	Ozone	Sunlight

The important points to be brought out from this table are:

- A variety of materials are damaged by common air pollutants.
- Sulfur oxides figure prominently as a pollutant type which can cause damage to many materials.
- Air pollution is only one of the environmental factors that can cause damage to materials exposed to outdoor atmospheres.

The last mentioned point brings up the connection with acid rain. The corrosion of metals and damage to building stone as influenced by sulfur oxides require that moisture be present. In fact, in completely dry air metal does not corrode even when high concentrations of SO_2 are present. Furthermore, the rate of iron or steel corrosion is much more sensitive to changes in atmospheric humidity than changes in sulfur oxide levels. Therefore, one of the most difficult problems in assessing the effect of an air

pollutant (or acid rain) on materials is the isolation of that portion of total environmental effect that can be ascribed specifically to the pollutant.

At this time I would like to interrupt this testimony to present briefly a few slides that illustrate various types of material damage associated with air pollutants and moisture.

1. Corroded Downspout - St. Louis, 1950's
2. Eroded Limestone Statue - Old Calvary Cemetery, Long Island City, New York, 1979
3. Parthenon, Athens, Greece, 1979
4. Detail of Parthenon showing soiling and loss of surface detail, 1979
5. Erechtheum, Acropolis, Porch of Caryatides, showing restoration efforts, 1979

If we consider only the damage to metals and building stone and the joint effects of moisture and sulfur oxides, it is my opinion that more damage occurs from direct contact of SO_2 and sulfates with moist surfaces than from acidic rain falling on the surface. This mechanism appears to be consistent with the situation on the buildings in Greece where marble surfaces (calcium carbonate) in the presence of sulfur oxides are converted to the more soluble calcium sulfate, or gypsum. Then those areas exposed to rain are susceptible to leaching by rain which, in turn, causes erosion of surface detail. However, further careful research is needed to establish the exact mechanisms of such damage.

Many attempts have been made to estimate the costs of material damage caused by air pollution. Most such estimates are completely unreliable, largely because many assumptions are necessary, for example, assumptions on the quantities of materials exposed, the exact mechanisms of physical damage,

and the scenarios of material protection, repair and replacement.

Probably the most reliable estimate of air pollution damage costs was that by Gillette in 1975.* He limited his study essentially to metal corrosion believing at the time (1975) that damage costs to other materials - including buildings and monuments - were not significant. He estimated that total damage costs for SO_2 corrosion to metals was of the order of $900 million in 1968 and had been reduced to $75 million by 1972 (a reduction of over 90%) as a result of meeting the primary air quality standard for SO_2. He further showed that meeting the secondary standard in 1972 would have produced only insigificant further reductions in material damage.

This work illustrates another of the fundmamental problems in estimating the extent of material damage. Efforts to control air pollutants have significantly reduced ambient levels in urban areas of several of these pollutants. Damage identified today and measured today may have been the result of earlier exposures at much higher concentrations of pollutants.

A further complicating factor is that there have been significant changes in the types of materials and protective coatings exposed to the atmosphere. These technological changes include the increased use of materials more resistant to pollutant damage. Our "throw-away" economy has also had a fundamental effect upon the nature and extent of air pollution-induced damage to materials and associated damage costs. Materials are often discarded long before the effects of air pollution become significant.

The recycling and preservation of old buildings as a result of high costs for new construction and a greater interest in our national heritage and its architecture is one aspect of our economy that is counter to our throw-away

*Gillette, D. G., "SO_2 and Material Damage", J. Air Pollution Control Assoc., 25:1238, 1975.

tendencies. This phenomenon will place increased importance on effects of air pollution, acid rain, and other environmental stresses on older material surfaces, because use life of materials is a key element in determining damage costs.

In summary, I have tried to make the following points:

- Air pollution and acid rain are capable of damaging materials, but more work is needed to establish the most important mechanisms of damage.
- There are no accurate estimates of the extent of the physical and economic damage. Studies are needed to establish these factors, especially during this period of increasing reliance on coal as a fuel and raw material.
- In those parts of our economy where we are attempting to preserve buildings and structures, special attention should be given to the air pollution and acid rain damage scenarios and the costs for preservation and maintenance.

APPENDIX

OhioEPA

October 7, 1980

The Honorable Gaylord Nelson, Chairman
Select Committee on Small Business
United States Senate
424 Russell Senate Office Building
Washington, D.C. 20510

Dear Senator Nelson:

As your committee researches the causes and effects of the acid rain phenomenon, I would commend to your attention a comprehensive research report on the subject prepared by Battelle Columbus Laboratories.

An executive summary of the report is enclosed.

For reasons spelled out in the summary, the report concludes that "there is a need for better and more reliable information to make environmental decisions on a rational basis."

This conclusion is shared by a number of equally highly regarded scientists in this field. Clearly we need much more accurate information regarding the problem in order to arrive at a workable solution.

It is a reasonable expectation that your committee will withstand the temptation to embark on hasty and unfounded programs which are touted to be instant solutions, but which may well do more actual harm than good.

Very truly yours,

James F. McAvoy
Director

JFM:tln

Enclosure

State of Ohio Environmental Protection Agency
Box 1049, 361 E. Broad St., Columbus, Ohio 43216 - (614) 466-8565

James A. Rhodes, Governor
James F. McAvoy, Director

RESEARCH REPORT

to

AMERICAN ELECTRIC POWER
SERVICE CORPORATION

on

OVERVIEW SECTION:

SUMMARY, OBJECTIVES, CONCLUSIONS AND PROJECT ORGANIZATION

by

Project Manager Joseph H. Oxley

and

Sanford G. Bloom
W. Terry Dana
Richard B. Engdahl
Samuel Globe
Danny R. Jackson
Harvey S. Rosenberg
J. Richard Scherr
Chester W. Spicer
Philip R. Stickael

September 1, 1980

BATTELLE
Columbus Laboratories
505 King Avenue
Columbus, Ohio 43201

Nitrogen Oxides

Nitrogen oxide emissions are believed to come primarily from transportation equipment in both countries, especially the automobile. In addition, nitrogen oxides are emitted by power plants and other industries. Furthermore, nitrogen compounds enter the biosphere as a result of farming practices.

Other Emissions

Other airborne industrial emissions that may affect the acidity of rain are believed to be minor, except perhaps in a few localized situations. Hydrocarbon emissions from forests that may produce acidic compounds directly or indirectly are appreciable, but little has been done to establish their importance as compared with man-made sources of acidity.

Measurements and Records

Modern scientific instruments are well engineered to identify and quantify the presence of the oxides of sulfur and nitrogen. Nevertheless, improvements in these instruments are desirable. Also, substantial improvements are required in the techniques to measure the acidic products of sulfur and nitrogen oxides. The instruments for measuring acidity of precipitation are now highly developed, although operation of such equipment is sometimes less than satisfactory. Furthermore, many of the early records on lake and rain acidity may be seriously in error because of the deficiency of the instruments that were used.

Distribution of Acidity

Studies to determine the spatial and temporal distribution of acidity in rain, and in surface and ground waters across the world, are now being very aggressively pursued. Rainfall in most parts of the world is moderately acidic due in part to carbon dioxide saturation, but more acidic in regions of industrial and

urban development. The acid content in rain, above that due to carbon dioxide, is generally about 60 percent sulfuric acid and 30 percent nitric acid, the balance being due to various other acidic substances. However, there are some exceptions to this rule. The Como Creek Watershed in Colorado, and several regions in California--at least during the rainy season--display acidity that is due primarily to nitric acid. Snow frequently has more nitric than sulfuric acid as its acidic component; and the acidity in snow melts is sometimes blamed for fish kills. The records for determining the change of acidity with time are not well established, but the acidity in rain would be expected to follow the rate at which acidic substances are emitted into the air if rainfall patterns are consistent over the years. Over the past half century, any increase in acidity in the U.S. from man-made sources could be attributable mostly to nitrogen oxides.

Predicting Acid Rain Transport

The ability to predict where this acidity will fall is not yet a well-established scientific discipline. General air flow patterns indicate where most of the acidity from a given source tends to be transported. However, at present it is not possible to predict long-range (about 1000 kilometers) transport of acidic substances in the atmosphere with desirable accuracy. On the other hand, there are probably some cases where the impact of a sufficiently large point source--and possibly a sufficiently dense regional source, such as a large metropolitan city--can be predicted with sufficient accuracy at intermediate distances (about 500 kilometers).

Effects of Acid Rain

It is difficult to show that acid rain has caused significant damage to the environment in the U.S. One can see some signs of recent erosion of rocks in New Hampshire, or damage to vegetation in New York, which can be explained on the basis of the acidity of rain. But the damage can be explained by other factors as well. Some lakes and streams show apparent increases in acidity, although the early records are poorly documented. Much of the blue haze associated with forested regions is generally believed to be caused by the interaction of sunlight with natural and man-made emissions. Some crop damage has been claimed; but occasionally beneficial effects are noted.

Research Needed

There is a need to know more about the separate effects of the various components in rain on the ecosystem, not only the acids and alkalis present, but trace amounts of toxic materials as well. Further basic research is desirable on the chemistry and deposition mechanisms involved in acid precipitation. A major instrumentation need, at present, is believed to be the capability to rapidly characterize varying precipitation events.

Other Factors Involved

There are other factors involved in the effects attributed to acid rain. The role of organic acids has generally been neglected in past work. The reactions of pollutants with natural products in the affected region need to be studied. The factors leading to the natural acidity of some lakes need study. Prior environmental insults to affected regions need to be documented.

Further analysis of existing data bases, and further investigation of the mechanisms of long-range transport of acidity are

Additional Research Needs

needed to improve the ability to predict long-range transport. There is insufficient information on nitrogen oxide behavior in plumes. Longer-term operation of the current monitoring networks is essential, and private industry initiative in this area should be encouraged. The health effects of acid rain and acid fog need to be established with much greater certainty. Also needed is effort on the role acid rain plays on the corrosion of materials. Finally, more effort is needed in field research and monitoring of aquatic and terrestrial ecosystems.

Clarifying the Problem

Acid rain is known to be a problem in some areas of the world. Whether or not it is now a significant problem in the United States is difficult to establish. It is difficult to demonstrate convincingly by direct measurement that the acidity of rain has significantly increased in the United States in recent times. However, the trends indicate that there may be a problem, and there is a need for better and more reliable information to make environmental decisions on a rational basis.

OBJECTIVES OF THE PROGRAM

This study was initiated by the American Electric Power Service Corporation to assess and summarize current knowledge concerning acid rain. The objectives of this study were to:

1. Determine what is currently known about the formation, transport, deposition and the effects of acid rain from an environmental standpoint
2. Determine what research efforts are currently under way or planned on acid rain
3. Determine what additional research efforts are needed, if any, to permit rational conclusions and recommendations concerning the environmental causes and effects of acid rain.

The technical subjects assessed within these objectives were the following:

1. The sources, both natural and man-made, of sulfur, nitrogen, and other emissions which might affect the acidity of rain
2. The chemical reactions of sulfur oxides and nitrogen oxides with other compounds of the atmosphere
3. The measurements of compounds present in the atmosphere which may affect the acidity of rain

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4. The spatial and temporal distribution of these compounds
5. The transport rates and patterns of airborne compounds of sulfur oxides, nitrogen oxides, and other compounds which might affect the acidity of rain
6. The deposition rates of these compounds
7. The potential effects of deposited compounds of acid rain on
   a. Man
   b. Land
   c. Vegetation
   d. Animals
   e. Water
   f. Fish
   g. Materials
8. The actual effects of these deposited compounds as identified to date
9. The information base that provides evidence as to whether or not the above factors have changed with time.

Although the problem is worldwide, most of the effort was directed toward summarizing the information which pertains to the eastern half of the United States and Canada.

CONCLUSIONS

The program was divided into six project areas—sources of emissions, measurement technologies, chemical reaction, airborne transport, distribution of contaminants, and environmental effects. Task groups drawn

from respective areas of scientific expertise were assigned to the various projects. Each group reached its own independent conclusions about the material it reviewed. Their findings are condensed and presented in less technical language in this overview document for the convenience of readers.

Sources and Amounts of Emissions

1. Over the past half-century, man-made emissions of sulfur oxides in the U.S. have increased. However, the exact degree of increase is uncertain. Currently, the best estimate is that the sulfur-based emissions amount to 25 to 30 million metric tons per year.

2. The amount of man-made nitrogen oxide emissions in the U.S., which have increased at a relatively high rate in recent years, is estimated to be in the range of 20 to 25 million metric tons per year.

3. There is less certainty about other emissions, both natural and man-made. Natural emissions--for instance, of hydrocarbons from forests, and ammonia from various sources--are thought to be substantial.

4. If new standards--based on the impact of such emissions--are to be established, there is a substantial need for refining the existing emissions data. Also, specific areas might be selected for updating of emissions data, because of their special importance to the acid rain issue.

5. Because of the huge amounts of natural organic material emitted into the atmosphere, and because their reaction products with various pollutants are known to be environmentally harmful, further work on the chemistry involved--and the environmental effects--is suggested for serious consideration.

Measurement Technologies

1. The substances that are thought to have the greatest effect on excess acidity in precipitation are sulfur dioxide and nitrogen dioxide, two acidic gases which are emitted directly into the air by urban and industrial sources; sulfuric and nitric acids, that are produced from these gases by chemical reactions in the air; and ammonia, present in the atmosphere from a number of natural sources. In order to understand their behavior in the atmosphere, accurate measurements of these substances are necessary.

2. Using modern instruments, scientists can measure sulfur dioxide concentrations from one part-per-million to 5 parts-per-billion. This is adequate for most applications, but it would be desirable to be able to measure down to about 0.5 part-per-billion for precipitation studies. Improvements also are needed in instruments that measure concentrations of nitrogen oxides. For example, measuring methods capable of detecting nitrogen dioxide down to 0.05 part-per-billion are needed to accurately assess how this gas interacts with rain.

3. Although a large variety of methods to measure ammonia is available, further development of several of these methods is required to assure dependable measurements.

4. Further improvements are needed in the techniques to distinguish between and quantify the components of sulfur-based acids.

5. Most of the early work on measuring the acidity of waters in New England was done with outdated techniques. Modern technology has produced more reliable equipment. Considerable caution should therefore be used in making conclusions based on early data. Even now,

any claim of extreme values in acidity should be verified by independent measurements.

Chemical Reactions

1. Chemical analysis of 11 years of precipitation in the northeastern U.S. shows that rain in this area contains a dilute solution of sulfuric and nitric acids, together with other contaminants that include some weakly acidic organic material. For the most part, sulfuric and nitric acids are not emitted directly to the atmosphere but are produced by the oxidation of sulfur and nitrogen dioxides. However, there is not agreement among atmospheric scientists on how the oxidation occurs.

2. Under most circumstances, organic acids contribute very little acidity to precipitation containing strong acids. However, there may be seasons and locations where the contribution of organic acids may be important. Additional measurements of organic acids in precipitation samples from diverse locations around the country are recommended to pin down the contribution of these largely naturally occuring substances.

3. The neutralization of acid gases and particles by atmospheric ammonia occurs very rapidly. However, in some cases, such as urban and industrial plant plumes, the acids are so concentrated that the atmospheric ammonia becomes depleted, leaving the acids unneutralized. It is currently believed that the effects of the neutralized or partially neutralized acids are nearly as important as the unneutralized acids, because the ammonia, itself, may be involved in acidifying the soil. This is an important consideration and should be more fully explored.

4. The degree to which natural sources contribute to atmospheric nitrogen dioxide, and thereby produce nitric acid, is uncertain. The available evidence suggests that nitrogen oxides are generated by lightning in thunderstorms and may possibly serve as a source of acid precipitation. However, in areas of high emission density, such as the eastern U.S., lightning cannot compete with man-made emissions as a source of nitrogen oxides.

5. Areas in which additional research is required include: (a) the mechanism and rates of oxidation of sulfur and nitrogen dioxides, (b) atmospheric measurements of cloud water composition and acidity, (c) a major field program on nitrogen oxide transformations in power-plant plumes.

Airborne Transport

1. The processes which affect the atmospheric transport of pollutants have been extensively studied for regions near the source (within 10 kilometers). There are many data for this region from which transport estimates can be made by a relatively simple procedure. In the absence of storms, rough terrain, or other disturbances, such estimates are relatively accurate (within a factor of 2) for distances up to 10 kilometers, less accurate but still generally applicable out to 50 kilometers, and usable only with much caution out to 100 kilometers. However, under more difficult conditions and circumstances, there is much uncertainty regarding the atmospheric transport of acid rain. More research is needed to improve predictive capabilities for atmospheric transport over large distances.

2. The effects of the pollutants are found at large distances (hundreds of kilometers) from their sources. In traveling these distances, the pollutants may encounter significant changes in wind speed and direction, intense turbulent mixing, major temperature fluctuations, nonuniform terrain, and various precipitation events.

3. The most common wind flow in the northeastern U.S. is from the southwest and west to the northeast and east. Thus, contaminated air from Ohio, Kentucky, West Virginia, Indiana, Michigan and Pennsylvania will generally move into New York and New England. Similarly, Ohio receives some acidity from emissions in Kansas, Missouri, Alabama, Tennessee, and Illinois. Air and emissions from New York commonly move into New England, except during the winter when the flow is from the northwest to the southeast across this region. Research in New York and Europe has shown that air mass trajectories which pass over industrial and urban areas bring higher sulfur-based concentrations than do trajectories with origins in other areas.

4. There is some uncertainty and disagreement concerning the transport of sulfur-based substances between the U.S. and Canada. The exchange appears to be seasonally dependent. Nearly half of the Canadian sulfur emissions are believed to come from several small areas where nonferrous smelters are located, while most U.S. sulfur dioxide emissions come from fairly uniformly distributed electrical and industrial plants. Thus, the effects of the concentrations involved, as well as the total amount transported, should be considered. Sources of nitric-oxide emissions tend to be somewhat more uniformly located in proportion to population in both countries.

Distribution of Contaminants

1. From data obtained in the Battelle-operated Multi-State Atmospheric Power Production Pollution Study--which focuses on the northeastern U.S.--pollution concentrations in acid rain show no statistically significant trends in time. However, the records for this study cover only the last three years.

2. There are strong positive correlations among the concentrations of acid rain constituents--particularly sulfur, nitrogen, and ammonia related substances. This conclusion applies to the inland northeastern U.S. sites primarily, where longer records are available. Midwestern and coastal sites have more complex precipitation chemistries, and analyses of their rainfall require further study.

3. Several acid precipitation-related pollutants show easily identifiable seasonal correlations. The sulfur-based pollutants have concentrations that are low in the winter and high in the summer. The ammonia constituent has a less distinct cyclical variation. But nitrogen-based pollutants appear to be relatively constant throughout the year.

Environmental Effects

1. Few studies have been reported on the direct health risks from exposure to acid precipitation. Potentially, however, the increased presence and ingestion of heavy metals in acidified drinking water represents the most significant potential effect of acid rain. Further research of this potential effect is recommended.

2. The acidification of lakes in Scandinavia has been attributed to acid rain for 20 to 25 years. More recently the increased incidence of acidic lakes has been noted in the northeastern U.S. and eastern Canada. Although this condition has been attributed to acid precipitation, the lack of definitive long-term data makes this conclusion somewhat uncertain. The fact that lakes of greatly differing acidity levels lie in close proximity to each other underscores this uncertainty. Some observed effects of acidified lake ecosystems include uptake of toxic metals by aquatic biota; loss of young fish and other aquatic animals; and elimination of algae and other aquatic plants.

3. The actual effects of acid rain on vegetation and soils have not been documented; most studies have been conducted under controlled environmental conditions using simulated acid rain. Frequently, the simulated rain was more acidic than natural rain. Still, the effects from the controlled studies are important because they may forewarn of effects on natural environment. The effects to vegetation observed in controlled studies include: injury to leaves and induction of deadly lesions in numerous crops and trees, both inhibition and stimulation of seedling germination and growth of crops and trees, and increased incidence of diseases in certain crops. Similarly, under controlled experiments, a variety of harmful effects--and some beneficial effects--on soil have been observed.

4. Extensive research is needed to further elucidate the precise magnitude and consequences of acidification on both aquatic and terrestrial ecosystems. Long-term field studies should be initiated to determine the ecosystems' responses to different levels of acid precipitation. The Adirondack region would be ideal for such experiments.

5. Acidic air pollutants including acid precipitation are known to accelerate corrosion of man-made materials and structures. Materials susceptible to corrosion by acid precipitation include: metals, building materials, paints, leather, and fibers. Technical-economic research of such corrosion expected under current levels of acid precipitation is desirable.

PROJECT ORGANIZATION

The project was organized to obtain the best talents available at both U.S. laboratories of Battelle in all of the technical areas proposed for study. Six project areas were assigned to the following Task Leaders:

(1) Sources of Emissions	Mr. Richard B. Engdahl
(2) Measurement Technologies	Dr. Chester W. Spicer
(3) Chemical Reactions	Dr. Chester W. Spicer
(4) Airborne Transport	Dr. Sanford G. Bloom
	Dr. Philip R. Stickael
(5) Distribution of Contaminants	Mr. M. Terry Dana
(6) Environmental Effects	Dr. Danny R. Jackson

These experts are well known to the scientific community in their areas of specialities.

Mr. Engdahl has been active in air pollution technology since about 1936, and has received the Frank Chambers Award of the Air Pollution Control Association and Percy Nicholls Award of the Fuels Division of the American Society of Mechanical Engineers.

Dr. Spicer has his Ph.D. degree in Analytical Chemistry from Pennsylvania State University in 1971, with a minor in air pollution chemistry. More recently, he has specialized in studies on the kinetics of oxide reactions in the atmosphere for the United States Environmental Protection Agency and the Electric Power Research Institute.

Dr. Bloom has his doctorate degree from Ohio State University and has been developing environmental dispersion models at Battelle since about 1965.

Dr. Stickael is the Senior Meteorologist at Battelle-Columbus and has recently been involved in experimental atmospheric dispersion studies above Boston, Massachusetts and Columbus, Ohio.

Mr. Dana has managed the network for Multi-State Atmospheric Power Production Pollution Study in the northeastern U.S. since its inception.

Dr. Jackson has his graduate degrees in Soil Chemistry from Colorado State University and has been engaged in studies on nutrient cycling processes at Oak Ridge, Los Alamos and Battelle since then.

These Task Leaders selected their own support staffs. The various sections of this report were authored by these Task Leaders, and the conclusions presented represent their analyses, and those of the other members of their task team, of the available data in the assigned area.

The Project Manager, Dr. Joseph H. Oxley, selected Task Leaders, was responsible for coordinating the effort, and led almost all field interviews and inspections. He obtained his doctorate from the Coal Research Laboratory of Carnegie Institute of Technology in 1956. He prepared the report summary and introduction, and approved the conclusions of the various Task Leaders.

Dr. Samuel Globe, Director of the Battelle-Columbus Research Council, reviewed and approved the report summary after it was assembled in draft form. Dr. Harvey S. Rosenberg, internationally recognized for his work on control technology, was the Deputy Project Manager. The project was carried out under the administrative responsibility of Dr. J. Richard Schorr, Manager of BCL's Energy and Environmental Technology Department.

Field interviews were held with representatives of the Electric Power Research Institute; the Edison Electric Institute, the National Coal Association; the States of Ohio, Pennsylvania, Massachusetts, Vermont, New Hampshire, and New York; federal officials and scientists of the United States, Canada, United Kingdom, Norway and Sweden; and various individuals throughout the northeastern United States, southeastern Canada, and northern Europe. Numerous bodies of water in the Adirondacks claimed to be affected by rain acidity were inspected by Battelle.

Information examined by the staff came from the generally available scientific literature, Battelle's own data bases, and from the field interviews.

The names of various individuals who assisted by presentation of new or updated information on the subject of rain acidity are listed below.

Alan Van Arsdale	Massachusetts Department of Environmental Quality Engineering
Valentine J. Descamps	United States Environmental Protection Agency - Region I
Ronald E. Towne Kenneth D. Warren	New Hampshire Water Supply and Pollution Control Agency
Gene E. Likens	Cornell University
Reginald A. LaRosa	Vermont Agency for Environmental Conservation

Richard Klein	University of Vermont
Ruth C. Clusen	United States Department of Energy
Martin E. Rivers	Environment Canada
William N. Poundstone	Consolidation Coal Company
Robert G. Skinner	Canadian Department of Energy, Mines and Resources
Steven R. Reznek Lowell Smith	United States Environmental Protection Agency
Frank Frantisak	Noranda Mines Limited
Ronald A. Barnes	Esso Petroleum Company, Ltd.
Gilles Robitaille	Canadian Forestry Service
David W. Schindler	Canadian Department of Fisheries
Charles A. Falcone Sam Ruggeri John M. McManus	American Electric Power Service Corporation
T. Craig Weidensaul	The Ohio State University - Wooster
Warren Schwartz Art Levy Dan L. Chase Theodore J. Thomas Robert W. Coutant Peter Van Voris Mickey F. Arthur Suzanne S. Groet Steven E. Pomeroy Ann W. Rudolph Caroline J. Warling George M. Sverdrup Michael R. Kuhlman Jeffrey L. Means	Battelle Columbus Laboratory
Jeremy M. Hales Ron L. Drake	Battelle Northwest Laboratory
Tom Brand	Edison Electric Institute
Neal S. Tostenson	Ohio Mining and Reclamation Association
John K. Weglo	Falconbridge Nickel Mines, Ltd.

Jeff Root	Teknekron Research, Inc.
J.C. Noggle	Tennessee Valley Authority
Michael R. Deland	ERT, Inc.
Elmar R. Altwicker	Rensselaer Polytechnic Institute
Danny Rambo	U.S. Environmental Protection Agency, Corvallis Laboratories
John F. Boyer, Jr.	Bituminous Coal Research, Inc.
Leon S. Dochinger	U.S. Department of Agriculture, Forest Services
Rick Linthurst	North Carolina State University
Maria H. Grimes	Library of Congress
Joseph Mullan	National Coal Association
Gary L. Triplett James M. Salvaggio Bill Pennavill	Pennsylvania Department of Environmental Resources
Fred W. Johnson	Pennsylvania Fish Commission
Gary N. Lee Patrick J. Festa Sid Marlow Ted Davis Peter R. Coffey Bill Marleau Mark Smith	New York Department of Environmental Conservation
James E. Gibson	Colorado State University
Kurt E. Yeager Ralph M. Perhac Robert A. Goldstein	Electric Power Research Institute
David S. Shriner Steve Lindberg Dale Johnson Sandy McLaughlin Phil Walsh Sylvia Talmage Carolyn Tucker	Oak Ridge National Laboratory

John Rôden Bo Assarsson Lars Lindau Birgitta Tims	The Swedish Government
A.J. Clarke F. Fraser Ross	Central Electricity Generating Board
C. Warling G.E. Glass	U.S. Environmental Protection Agency, Duluth
Richard A. Fleming	Ontario Hydro
Arne Tollan	The Norwegian SNSF Project

The Appendix of the Full Report contains position statements submitted by or from the following individuals and organizations:

Robert G. Skinner	Canadian Department of Energy, Mines and Resources
Frank Frantisak	Noranda Mines Limited
James F. Boyer, Jr.	Bituminous Coal Research, Inc.
Martin E. Rivers	Environment Canada
Ruth C. Clusen	United States Department of Energy
William N. Poundstone	Consolidation Coal Company
James F. McAvoy	Ohio Environmental Protection Agency
A.J. Clarke	Central Electricity Generating Board
Bill Pennewill	Pennsylvania Department of Environmental Resources
Robert Trumble	Library of Congress
Samuel Huntington	New England Electric System
Ralph M. Perhac	Electric Power Research Institute
Douglas M. Costle	U.S. Environmental Protection Agency
Robert A. Flacke	New York State Department of Environmental Conservation
Reginald A. LaRosa	Vermont Agency of Environmental Conservation

Arne Tollan	The Norwegian SNSF Project
Lars Lindau	The National Swedish Environmental Protection Board
Terry London	The Sierra Club

These summary statements are believed to be an unusually concise compendium of other views on the subject of acid rain, and the interested reader is encouraged to review this material as well. It may be noted that a number of these observers believe that the claims that acid rain has caused widespread damage in the United States are blown considerably out of proportion in view of the available evidence. Indeed, claims of damage frequently seem to be exaggerated, often to a degree that the public has become confused on the issue of acid rain. Others clearly point out the long-range seriousness of the problem to the public if significant amounts of current damage can be scientifically documented in the United States.

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